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U. S. NAVAL AIR DEVELOPMENT CENTER
JOHNSVILLE, PENNSYLVANIA

(14) Anti-Submarine Warfare Laboratory

REPORT NO. NADC-AW-6103 (6) PHASE REPORT, INVESTIGATION OF POSSIBLE IMPROVEMENTS TO SONOBUOY LAUNCHERS AND RETARDATION DEVICES TO DECREASE THE ERRORS FOUND IN SONOBUOY SPACING.

BUREAU OF NAVAL WEAPONS
TED Project No. ADC AV-34054

(11) 28 June 1961 (12) 73p.

This report presents the results of a controlled flight test program to investigate possible improvements in sonobuoy launching and retardation equipment for the purpose of decreasing errors in sonobuoy spacing.

The P2V aircraft standard sonobuoy launching equipment with modifications by the Naval Air Development Center (NAVAIRDEVCEN) to launch stores at various angles to the aircraft horizontal datum plane and orient the retardation means within the launching tube was evaluated under actual flight conditions to determine the effect on sonobuoy trajectory and placement accuracy.

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SUMMARY AND CONCLUSIONS

INTRODUCTION

TED Project No. ADC AV-34054, established by reference (a), requested the Naval Air Development Center (NAVAIRDEVCEN) to investigate possible improvements to sonobuoy launchers and retardation means to decrease errors in sonobuoy spacing. Also, an investigation was requested of possible distance measuring devices (DME) to measure the actual sonobuoy spacing on the water.

At NAVAIRDEVCEN, a study was made of the nature of the air flow in the region of the sonobuoy ejection points on the P2V aircraft. Analysis of the airloads acting on sonobuoys at launch indicated the optimum position of the launching chutes to be between 30 and 40 degrees from the aircraft horizontal datum plane. This would permit the longitudinal axis of the sonobuoy to be nearly parallel to the aircraft slipstream at ejection. Thus, the sonobuoy on ejection would not be subjected to an unbalanced moment which would produce a tumbling action and resultant inconsistent drop patterns.

Concurrently, the present sonobuoy retardation system was investigated.

SUMMARY OF RESULTS

The effect of the sonobuoy launch attitude on the placement accuracy was found to be of little significance for the four launcher tilt angles evaluated.

However, the influence of orientation of the rotochute blades in the launching chutes produced much wider variations in the values of their standard deviations. The standard deviations are shown in table VI.

The total azimuthal error was represented by the angle formed by the reported aircraft course and a line through the impact locations made by each pair of sonobuoys on the ground. The values of the standard deviations for this error were 4, 5, 5.5, and 7.8 degrees for the respective launcher attitudes of 90, 70, 45, and 30 degrees.

There is evidence of erratic rotochute blade acceleration and even of momentary deceleration after launching and during descent. The design and materials employed in the rotochute bearings are probably at fault, there being visual evidence of high friction loads and possibly of seizing. The opening action of the rotochute blades is erratic and is influenced by blade orientation in the launcher chute, particularly in the 70-degree attitude. The use of four bladed rotochutes imposes a requirement for restriction of blade orientation. The use of a greater number of blades could relieve this requirement. Design effort has been initiated on improved rotochute blade systems to incorporate the lessons learned and also to provide additional space for electronics and other equipment such as DME.

CONCLUSIONS

Analyses of the results of the flight test program indicated that:

1. None of the four sonobuoy launcher angles evaluated was significantly superior to any of the others with respect to placement accuracy.

2. The orientation of the rotochute blades with respect to the line of flight at the 45-degree white and the 70-degree blue position provided the lowest values, for the four angles tested, in the standard deviations of the spacing distance.

3. It is extremely important that the rotochute blades of both sonobuoys in a pair be rotated to the same orientation when the sonobuoy is placed in the launching chute.

4. The present sonobuoy firing apparatus and circuitry permits variable delays in the launching cycle.

5. The present sonobuoy rotochute and bearing design is far from optimum.

6. There has been inadequate dimensional and design control over launching equipment and sonobuoys. This conclusion is based on a study of detail and assembly drawings of the launchers which does not appear in this report. The uniformity of launcher assemblies could be improved by the establishment of gaging dimensions and tolerances for these assemblies and component subassemblies.

While international limitations on length and maximum diameter of sonobuoys are useful, precise ballistics require more stringent controls which cannot be obtained from the usual sonobuoy performance specifications. Lack of Navy-wide standards establishing identical sonobuoy external configurations, rotochute design, mass distribution, etc., will add ballistic variations to the deviations shown herein for identical dummy sonobuoys.

RECOMMENDATIONS

On the basis of the foregoing, it is recommended that:

1. Further study be made to incorporate the advantages of specific combinations of launch angle and blade orientation into a more efficient and positive sonobuoy launching system.

2. A study be made of the probable value of a means affording simultaneous rotochute blade opening.

3. Fleet activities be advised of the necessity, as an interim measure, to rotate each sonobuoy carefully, upon insertion in the launching chute, so that the end of one of the blades, and not the bumper or springplate, rests upon the stores-ejector foot. When this is done the sonobuoy rests

about one-half inch lower in the launching tube and uniform blade orientation is assured. This procedure is the only means that can presently be employed to insure satisfactory operation where spacing is critical.

4. The present aircraft electrical sonobuoy firing circuitry be modified to eliminate all component time delays.

5. A system be established for continuous review of all proposed changes in sonobuoy retardation, configuration, mass distribution, and proposed modifications to the aircraft launching systems to evaluate the effect of each upon the other before final approval.

6. The bearing in the sonobuoy retardation system be improved and consideration be given to modifications which will yield more uniform trajectories.

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BACKGROUND

Unreliable operation of the standard P2V aircraft sonobuoy launching system during exercises employing certain tactics requiring accurate spacing were reported in reference (b). Departures of 144 feet from an intended spacing of 350 feet and divergencies up to 20 degrees in angular baseline orientation were observed. The causes for these errors were attributed to the angle at which the sonobuoy entered the air stream from the airplane and to inconsistencies in the period of ejector actuation time.

In reference (c), marked improvements were reported in the spacing accuracy between sonobuoys ejected from a temporary installation of two launchers inclined at 45 degrees to the horizontal datum in a P2V airplane. This letter included the recommendation that additional tests of a 45-degree installation be performed to obtain sufficient data to determine the suitability of such launchers for installation in all P2V aircraft that accommodate sonobuoys whose spacing is critical.

It was decided to conduct a series of controlled flight tests over land to evaluate the effects of various launching angles and of the orientation of the rotochute blades in the launching chute on the sonobuoy placement accuracy. The accuracy was to be determined with respect to a prescribed course and spacing between sonobuoys consecutively launched in pairs.

Experimental sonobuoy launching equipment with two tubes and the capability of varying the launch angle from 90 to 30 degrees with respect to the airplane horizontal datum plane was designed and installed in the P2V-5 airplane, BuNo 131403, by the NAVAIRDEVCEN. This installation is shown in figure 1.

EQUIPMENT AND INSTRUMENTATION

From January 7 through March 3, 1960, several series of tests were made on Drop Mat No. 4 at the Naval Air Station, Lakehurst, New Jersey, to determine the accuracy of spacing between sonobuoys of a pair and their angular placement accuracy when they were dropped from chutes tilted at various angles with respect to the horizontal datum, the sonobuoys having been initially rotated in the chutes at various specific orientations to the relative wind.

On Mat No. 4, a grid was laid out in 200-foot squares covering an area 2800 by 2800 feet, circumscribed by a graded area 4000 feet in diameter. The grid was oriented to magnetic north (figure 2). Conspicuous coded markers were arranged each day at selected locations with respect to the desired direction of the flight course. The markers were so keyed that its location, bearing, and speed of the airplane could be determined by comparing photographs taken from the airplane.

The sonobuoys were dropped from P2V-5 airplane, BuNo 131403. To measure intervals accurately, all drops were made over land, with four sonobuoys (two in the case of the 30-degree chute) being dropped in sequence, two from the 70-degree chute and two from either the 45- or 90-degree chutes. The resulting sonobuoy impact spacings and bearings of the various pairs were measured. Data were collected from a total of 472 dropped sonobuoys during 144 flight runs.

Runs were made at various courses, mostly into the wind. Since the wind direction varied somewhat during the day, data became available at various crosswind angles. All flights were made at 150 knots nominal indicated airspeed (IAS) and 500 foot altitude, except for one day when a 200-knot airspeed and 1000-foot altitude were used. Speed and altitude were corrected with reference to the ground in the data reduction process.

The test was made to determine the effect on the placement accuracy of various launch chute angles, various blade orientations, efficiency of launching equipment, and at the same time to study and make recommendations on rotochute performance.

Changes were made in the components of the sonobuoy launching system to improve its accuracy. A study of the electrical firing circuitry showed several relays that could produce time variations of 40 milliseconds in the launching cycle due to the normal variation within standard tolerances. The local modification of the circuitry is indicated in figure 3.

Some of the selector switches or relays are the normally open type and have variable time delays in closing. To eliminate this possibility, a normally closed type rotary relay, G. H. Leland, Incorporated, No. C-8341, was interposed in the circuit between the intervalometer and the ejector solenoids.

The intervalometer normally used in the P2V aircraft was the Navy type K-2. This unit was not reliable in operation at intervals less than 2 seconds between pulses. The requirement for a desired spacing of 350 feet at 150 knots was 1.38 seconds interval. The latest model intervalometer, Ordnance Release TD-239/A, serial 332, was used in all tests.

The latest available ASW pneumatic store ejectors, Model 7094.1, were procured and were used in all launching chutes.

Certain Fleet operations require that sonobuoys be dropped in sequences of two with a definite spacing and a known bearing. In order to establish a reference base, the sonobuoy launching chutes were arranged in pairs with two chutes inclined at 70 degrees and two chutes inclined at 45 degrees (or 90 degrees) for comparison. However, in the case of the 30-degree chutes, space and structural limitations precluded simultaneous use with the 70-degree chutes as a reference. Except as necessary to install supports and instrumentation, the Lockheed chutes themselves were not otherwise modified. See figure 4 for launching chute configuration and table I for the position of the several ejectors.

TABLE I

EJECTOR POSITIONS

Pneumatic Ejector Serial No.	Launching Chute Location No.	Angles at which Launchers were Positioned (deg)
0470	1	70 and 30
0458	2	70 and 30
0465	3	45 and 90
0459	4	45 and 90

The pneumatic system powering the ejectors was not altered. However, a pressure of 3000 psig was maintained in the air reservoir and reduced to 1000 psig for use in the ejectors. (See figure 5.) Although the limits used by the Fleet may be as low as 750 psig, the higher pressure will insure better and more uniform sonobuoy ejection.

In order to simulate the AN/SSQ-28(XN-1) sonobuoy in configuration and mass distribution, wooden dummies were made as shown in figure 6.

The dummies were painted fire orange with a one inch black stripe along their length. In order to facilitate accurate blade orientation of sonobuoys which are installed in the chutes in an inverted attitude, stripes oriented with the blade positioning lug were painted on the opposite end of the dummy sonobuoy. The purpose of the stripes was to facilitate analysis of the photographs. (See figure 7.)

RECORDING METHODS

High speed photography was employed to determine the functional operation of the rotochute, such as timing and sequence of blade openings, attitude and rotational speed. Other cameras were employed to determine the speed and altitude of the aircraft and the motions of the sonobuoy during descent. Its trajectory and velocity could be monitored throughout the descent.

The flight track of the aircraft was recorded by a series of aerial photographs made by a K-17 mapping camera installed in the fuselage of the aircraft looking down over the grid. (See figure 8.) These same photographs were used to check aircraft ground speed and the size and variation of navigational errors.

A Traid No. 200 camera was installed on the bottom of the fuselage aft of the radar dome (figure 9). This afforded high speed motion pictures (approximately 200 frames per second) of the ejection of the sonobuoys. When the intervalometer impulse reached the first ejector solenoid, the camera would begin operation. A thermal relay was installed in the camera circuit to allow the camera to operate for approximately 8 seconds. Both this camera and the Navy K-17 mapping camera were separately connected into the firing circuit of the first sonobuoy launching chute.

A tripod-mounted Traid camera was placed on the ground approximately 800 feet from and at right angles to the requested flight path of the aircraft. This camera could pan in azimuth and elevation to follow the trajectory of the sonobuoy from emergence to ground impact. This permitted the attitude of a selected sonobuoy in a pattern to be monitored throughout descent and permitted measuring the rotochute blade rpm during the latter portion of the drop. Film speed was about 120 frames per second.

A tripod-mounted K-17 mapping camera was also placed on the ground next to the Traid No. 200. At an exposure interval of approximately 0.7 second per frame, the photographs supplied a check upon the speed and altitude of the aircraft and also the trajectory and rate of descent of the sonobuoy. Thus, four cameras altogether were used.

The velocity and direction of the wind was determined at the site adjacent to the ground camera location by means of the AN/PMQ-3 Wind Measuring Set.

A recording oscillograph, CEC type 5-114 (figure 10) was installed in the aircraft to record the following data:

1. Time of pickle to intervalometer
2. Time of impulse to ejector solenoid
3. Air pressure in ejector cylinder throughout entire stroke
4. Air pressure in reservoir
5. Time of shutter opening in aircraft K-17 camera
6. Time of start of sonobuoy movement in chute
7. Time that sonobuoy was ejected from chute.

By the use of this especially designed instrumentation, all timing of the functional operation of the ejectors, the speed of ejection, air pressures and other desirable intelligence was acquired and recorded. From this, the determination could be made between the functional, launching, and navigational errors for evaluation.

Photocells, "Clairex" Model Cl-2, were installed in the launching chutes to indicate passage of the sonobuoy. The photocells were inserted at the foot of the ejector just below the edge of the sonobuoy, so that the passage of the sonobuoy would break and remake the photocell circuit, affording an index as to the relative speeds of ejection.

The sonobuoys were dropped on the grid and the distances of each impact point from the two nearest grid markers were measured. The intervals between each pair of sonobuoy impact points were also measured. These measurements were checked later by calculations and accurate layouts.

S O N O B U O Y   P L A C E M E N T   A C C U R A C Y

Accurate sonobuoy placement is dependent upon two factors. The first is the ability of the launching system to position a pair of sonobuoys at a prescribed spacing distance in the water. The second is the knowledge of the azimuthal orientation of the two sonobuoys. For these tests, the sonobuoy placement accuracy is a function of the variance in the spacing between the impact points at a prescribed distance of 350 feet in the water and of the error in their angular orientation. In normal operations the aircraft crew would:

1. Fly at a known bearing and at IAS to produce the required ground speed, corrected for altitude, temperature, wind bearing, and velocity.

2. Set the intervalometer at the aircraft speed and the desired spacing.

With the exception of these two points, the placement accuracy is not controllable by the crew. No test was made in advance to determine the average intervalometer error under actual flight conditions. Bench tests had indicated that the intervalometer used in the tests met the specification requirements.

In the flight tests, it was essential that the aircraft fly on a prescribed course to permit accurate analysis of error resulting from variation in the trajectories of the sonobuoys and in the speed and altitude of the aircraft. Once on a course at a given speed, the aircraft was committed and no in-flight adjustment could then be tolerated. Navigational errors, however, were taken into account in determining the accuracy of a drop pattern and did not penalize the launching system.

Thus, it was necessary to correct the spacing between the impact points for flight speed and intervalometer error. The sonobuoy spacing error with respect to a desired spacing of 350 feet was determined for flight B-1 from table II as follows:

D = Final corrected distance between drops

D_g = Desired aircraft ground speed (150 knots)

D_m = Actual measured distance between impact points of sonobuoys (338 feet)

D_s = Actual aircraft ground speed, calculated from the IAS, altitude, temperature, wind velocity and bearing (153 knots)

t = Actual time of interval in milliseconds (1373)

T = Calculated interval between pulses in milliseconds (1381.5)

Therefore,

$$D = D_m \times \frac{D_g}{D_s} \times \frac{T}{I}$$

$$= 338 \frac{150}{153} \times \frac{1381.5}{1373} = 338 \times 0.981 \times 1.007 = 334 \text{ feet.}$$

This is 4 feet less than the 338 feet actually measured, leaving an unaccountable error (trajectory error) of 4 feet. The error from an operational standpoint would be 350 feet - 334 feet = 16 feet.

Thus, the spacing errors due to controllable and measurable factors are adjusted in the calculations to achieve a corrected spacing distance "D" between impact points.

Errors in spacing and azimuth fall into three classes: functional, navigational and trajectory. The functional error includes delays in the electrical and mechanical components of the complete launching system. The navigational error results from inaccuracy in reporting and recording of aircraft speed and bearing. The trajectory error is that which occurs after sonobuoy ejection and is the result of the direction and magnitude of the wind currents plus any anomalous performance of the sonobuoy rotochutes and their bearings.

FUNCTIONAL ERRORS

The functional errors are comprised of the intervalometer and the ejector errors, both items being susceptible of variations in operating time.

With the intervalometer used, it was necessary only to set it for ground speed and sonobuoy spacing. At the test setting required, 350 feet and 150 knots, the time between pulses should be:

$$\text{Time in seconds} = \frac{350 \text{ feet spacing} \times 3600 \text{ seconds}}{150 \text{ knots} \times 6080 \text{ feet per nautical mile}}$$

$$\text{Time in seconds} = 1.3815$$

A study of the schematic wiring diagram designed for this test (figure 3) shows that no time lag is introduced between the pulses of the intervalometer and the ejector solenoid. Thus, variations in actual time lapses are inherent in the intervalometer itself. These are itemized in table II.

SUMMATION OF INTERVALOMETER ERRORS

Desired time between pulses	1381.5 ms
Average time between pulses	1368 ms
Standard deviation about average time	4.6 ms
Standard deviation about desired time	15.4 ms

TABLE II

TABULATION OF TIMES BETWEEN INTERVALOMETER PULSES

Time (ms)	Number of Observations
1345	1
1348	1
1352	1
1357	1
1360	3
1361	1
1362	10
1363	24
1364	38
1365	32
1366	32
1367	21
1368	16
1369	26
1370	17
1371	13
1372	8
1373	3
1374	1
1375	4
1376	4
1377	2
1378	1
1380	4
1389	1

At 150 knots the aircraft speed is 253 feet per second, so the average error due to the intervalometer time lag of 13.5 milliseconds would be 3.42 feet. Compensation for the intervalometer error was included in the final calculations.

The ejector error is the variation in delay time from the instant the pulse arrives at the ejector solenoid until the sonobuoy is ejected from the launching chute. This error comprises four inherent variable errors for which no individual compensation can be made. These are summarized in table III and are defined below.

1. Variations in time between pulse and solenoid operation.

2. Variations in time between operation of solenoid and full air pressure on ejector piston.

3. Variations in time between pulse and photocell indication of sonobuoy movement in chute.

4. Variations in time required for the passage of the sonobuoy through the photocell beam.

TABLE III

EJECTION ERROR VARIABLES

	Time (ms) High	Low	Average
1. Pulse to solenoid operation	9	4	6.3
2. Solenoid operation to full air pressure	44	13	25.5
3. Pulse to interruption of photocell beam	50	31	42.5
4. Period of photocell interruption	149	129	138.4
Total time from pulse to sonobuoy ejection	199	160	180.8

A portion of the oscillographic record for flight B-2 is shown in figure 11. This illustrates the points at which the above values were obtained from the solenoid, photocell and airpressure traces. This is the record from chute position 1 at the 70-degree attitude.

From table III, the average time required to eject a sonobuoy was 180.8 milliseconds. Comparison of the manufacturer's ejection time data, marked on each ejector, with the above average is given in table IV.

TABLE IV

COMPARISON OF MANUFACTURER'S AND AVERAGE EJECTION TIMES

Manufacturer's Ejection Time on Ejector (ms)	Average Ejection Time - All Tests (ms)	Difference from Average (ms)
194.8	180.8	14.0
206.0	180.8	25.2
207.2	180.8	26.4
207.0	180.8	26.2

The error produced by the variation in ejection times would be the time difference between the average ejection, 180.0 milliseconds, and the actual ejection time for any one operation. From table III it is obvious that a wide variation in the period of ejection is possible. For example, compare two chutes, the first having the minimum or low time of 160 milliseconds, while the second chute has the maximum or high time value of 199 milliseconds. This is a total difference of 39 milliseconds and would produce an error of ±9.9 feet in spacing at an aircraft speed of 150 knots.

Summation of Ejector Errors

It was not possible to install a light source and photocell combination in launcher No. 2 because of structural interference. Thus ejector time variations could not be measured for any of the spacings from the 70-degree launching angle. The most comprehensive record of the ejectors operational periods was obtained from the 45-degree launchings. These values were used in determining the effect of the variations of ejector times on the spacing distance between sonobuoys. From a net sample of 42 observations of the differences in the recorded times of paired ejectors the average error was determined to be 1.85 feet. While it cannot be arbitrarily stated that those unmeasured ejector time variations would be of the same magnitude, the figure of 1.85 feet appears to be a reasonable assumption.

NAVIGATIONAL ERRORS

Under this heading are included all the errors due to navigation. These comprise the difference between the intervalometer ground speed setting and the actual speed, and the difference between the recorded aircraft track and its actual track across the test drop grid. Such errors may be linear or angular.

The ground speed of the aircraft can be controlled by the flight crew. If the actual ground speed is different from the intervalometer setting, a linear navigational error will result. As an example, if the intervalometer were set for 150 knots ground speed and the aircraft were flown at 151 knots, the error for a 350 foot spacing would be:

$$(350 \times \frac{151}{150}) - 350 = 2.34 \text{ feet or } 0.67 \text{ percent}$$

The values of angular error have been derived by plotting the various aircraft tracks against the sonobuoy impact points on the grid pattern of the test site. The angular navigation error is the difference between the course reported by the crew and the actual aircraft track as determined from the photographs taken by the aircraft mapping camera.

The total angular error for all pairs of sonobuoys is composed of two parts, navigational and trajectory. These are listed in table V. Under this heading that portion chargeable to navigation only will be considered. This error has two effects on placement accuracy. The first is the amount of change in the spacing distance. Since the average value of this angle in table V is only 3.5 degrees, the projected effect on a required spacing of 350 feet would be only 0.65 foot. The second, is a first order effect on target location intelligence, which though serious, is not appropriate for inclusion in this report.

TABLE V

TOTAL ANGULAR ERRORS AVERAGED FROM ALL FLIGHTS

	Average (deg)	Standard Deviation from Zero Degrees (deg)
Navigational Error Reported flight track to photo flight track	3.5	4.5
Trajectory Error Photo flight track to impact points track	4	5.5
Total Error Reported flight track to impact points track	5	6.5

TRAJECTORY ERROR

The sonobuoy trajectory error includes all those errors that occur during the sonobuoy's free flight between the time of ejection from the airplane and the time of impact on the ground, which have not been accounted for as functional and navigational errors. The trajectory error also produces linear and angular effects on sonobuoy placement accuracy similar to those imposed by the navigational error.

The trajectory linear effect is the difference between the spacing of the points of ejection of the sonobuoy from the airplane and the spacing measured between the sonobuoy impact points on the ground. Attention is directed to the fact that the following calculations for the spacing values include the effect of the two ejectors and two trajectories.

The spacing of the sonobuoy ejection points from the aircraft was calculated from the oscillograph record of the specific operational time period between the intervalometer pulses and the times required by each ejector to release its sonobuoy multiplied by the respective ground speed of the airplane.

The determination of the linear effect of the trajectory error for flight 2E is shown in figure 12 and the following calculation.

$T_{(L)}$ = Trajectory linear effect on spacing in feet

$D_{(m)}$ = Actual measured spacing between impact points in feet

V = Actual aircraft ground speed in feet/millisecond

I = Actual interval between pulses in milliseconds

E_1 = Ejection time 1st ejector in milliseconds

E_2 = Ejection time 2nd ejector in milliseconds

$$T_{(L)} = D_{(m)} - V\,(I \pm (E_2 - E_1))$$

$$V = 157 \text{ knots} = 157 \times \frac{6080}{3600} = 0.265 \text{ feet/millisecond}$$

$$T_{(L)} = 336 - 0.265\,[1375 + (170 - 164)]$$

$$= 336 - 366$$

$$= -30 \text{ feet}$$

The average total linear effect on the spacing accuracy from a total of 194 observations was 20 feet with a standard deviation of ±15 feet.

The trajectory angular error is indicated by the angle between the aircraft photographic track and the line through the impact points of a pair of sonobuoys projected on the test grid. The average value of this angle from all of the flights made, shown in table V, is four degrees. Its effect then is only slightly greater than that attributed to the navigational angular error.

As the values of the navigational and trajectory angular errors are obtained from the analyses of photographic data, the total angular error is indicated by the angle between the reported aircraft track and the line through the impact points of a pair of sonobuoys. The average value of the total error from table V is 5 degrees. The projected linear error for a desired spacing of 350 feet would be only 1.3 feet for an angle of this size.

The separate effects of the three types of error on sonobuoy spacing accuracy, indicated by the average values from the Lakehurst flight tests, are summarized as follows:

Functional	
Intervalometer error	3.4 ft
Stores ejector error	1.8 ft
Navigational	
Aircraft speed, error per knot	2.35 ft
Angular error	3.5 deg
Linear projection of angular error	0.65 ft
Trajectory	
Angular error	4 deg
Linear projection of angular error	1.3 ft
Linear error	20.0 ft

For any pair of sonobuoys, the total angular error comprises the algebraic sum of the airplane's navigational error and the angular trajectory error of the sonobuoy. This relationship does not remain true if the average values for a series of flights are used.

The following information is supplied to show the degree of accuracy of the data sources. The various aircraft tracks were obtained by plotting the center of the photographs taken by the airplane's type K-17 mapping camera on a scaled drawing of the grid pattern. The camera mount was fixed to the airframe and no correction was made for the natural frequency roll of the aircraft. Since the P2V airplane rolls approximately ±2 degrees at a rate of 3 to 6 cycles per minute and the time of flight across the grid was between 10 and 12 seconds, one set of photographs (10 to 12 frames) would be included between 1/2 to 1 full roll cycle.

A check on the pressure transducers installed in each ejector was made with a dead weight testing fixture. All were found to be accurate within a tolerance of ±5 percent.

The accuracy of the oscillograph used to record all time, pressure, and electronic indications, was determined to be 99.2 percent by means of an electronic counter.

A summary of the results of the flight test program is shown in table VII. A review of the spacing data is repeated here for analysis. These observations include those flights made at 200-knots airspeed and 1000-feet altitude.

Col. 1	2	3	4	5	6
Chute Angle (deg)	Number of Observations	Average Actual Measured Spacings (ft)	Standard Deviation (Actual) (ft)	Average Corrected Spacing (ft)	Standard Deviation (Corrected) (ft)
30	33	334.8	28.0	335.3	24
45	57	349.7	28.7	346.4	27
70	93	351.2	22.2	344.8	24
90	32	366.5	25.0	353.6	25

Under column 3 are listed the average values obtained from actual measurements on the ground of the spacings between the impact points of the number of pairs in column 2. In column 5 are the corresponding corrected spacing values adjusted for ground speed, altitude, and functional errors with their respective standard deviations. The variance of three feet between the maximum and minimum values of the standard deviations of the spacing from the four angles tested suggests that none of the launch angles is superior to another. Therefore, the sonobuoy aircraft launching angle has little significant influence on the placement accuracy.

The effect of the orientation of the sonobuoy rotochute blades in the launching chute does indicate that the results from some are definitely superior to others. For each angle of chute inclination tests were made with the rotovane blades inserted with certain relationships to the direction of aircraft heading. The orientations were identified by the colors white, pink, red, and blue representing 22.5 degree rotation intervals as shown in figure 13. The values of the standard deviations of the various spacings are presented in table VI.

TABLE VI

STANDARD DEVIATIONS OF THE VARIOUS SPACINGS

Launching Chute Angle (deg)	Blade Orientation	No. of Observations	Actual Measured Spacing (ft)	Standard Deviation (ft)	Corrected Spacing (ft)	Standard Deviation (ft)	ORDER
45	White	24	350.5	22.2	346.5	16.3	1
70	Blue	17	301.0	11.9	353.0	16.8	2
70	Red	22	341.5	22.4	337.5	18.7	3
30	Red	17	333.8	19.4	333.3	19.6	4
90	White	16	359.9	24.6	347.6	23.8	5
90	Red	16	370.0	23.4	357.0	24.0	6
70	White	24	351.2	22.8	347.7	26.0	7
30	White	16	335.9	25.2	337.5	27.0	8
70	Pink	20	349.7	25.3	338.6	29.0	9
45	Red	23	341.0	34.2	338.0	34.0	10

It can be seen that the two smallest values of standard deviation were obtained with the use of the 45-degree chute and white blade orientation and the 70-degree chute with the blue orientation. This is the basis for recommendation No. 3 on page ii. Sonobuoys oriented in the manner described therein will have their rotochute blades automatically positioned between white and blue but much closer to the blue than to the white.

The entire range of the standard deviations of the spacings is included between the white and red positions of the 45-degree launch angle, with the lowest value of 16.3 feet for the white and the greatest of 34 feet for the red.

It will be readily apparent that the orientation that yields the lowest value of standard deviation is best. It should be emphasised here that while both sonobuoys in each pair dropped during the test had identical blade orientations, the Fleet has never operated with this advantage. In order to show fully the handicap imposed on present operations, it is necessary to refer here to table VII. There it will be seen that the average time for full blade opening for 70-degree red, for example, is only 153 milliseconds while the average time for 70-degree white is 100 milliseconds longer. No actual determinations were made during the tests of the actual lengths of the trajectories for each orientation of blades;

yet they did vary greatly, generally as a function of blade opening time with the longer trajectories being characteristic of slow openings. Thus the difference in trajectory length for a 100 millisecond slower opening might approach 20 to 25 feet, in addition to the applicable standard deviations. It would appear, therefore, that it may not be at all uncommon for spacings to fall below 300 feet or to exceed 400 feet with random blade orientations.

Therefore, it can be concluded that sonobuoy rotochute blade orientation at launch does have a distinct influence on placement accuracy and that steps should be taken at the earliest possible date to remove this variable.

OBSERVATIONS ON SONOBUOY TRAJECTORY

Trajectory observations suggest many conclusions, some may be factually proven, some may be inferentially proven, while others are by inference only.

SONOBUOY CHUTE ANGLE AND BLADE ORIENTATION

1. It is shown that the angle of the launching chute (figure 5) has no significant effect on placement accuracy.

2. Provisions for setting identical orientations of the rotochute blades in all launchers will afford improvement in the linear spacing of sonobuoy impacts.

3. Furthermore, positive gains are indicated with the use of certain angles of ejection in combination with certain blade orientations as shown by the corrected values in table VII.

Thus the best combinations shown in the tests were:

45-degree chute white orientation - standard deviation 16.3 feet
70-degree chute blue orientation - standard deviation 16.8 feet
70-degree chute red orientation - standard deviation 18.7 feet

4. However, the use of random blade orientations in any one run could produce large errors in sonobuoy spacing.

5. From table VIII, it may be noted that certain combinations of launching chute angle and rotochute blade orientation produce wide variations in the three angular errors. By coincidence, with the combination of the 70-degree angle and pink orientation, the arithmetic sum of the navigational and trajectory errors is exactly equal to the total error of 2 degrees 37 minutes. All other combinations show a partly compensating influence that reduces the value for the average total angular error.

TABLE VII

CORRELATION OF FULL ROTOCHUTE BLADE OPENING WITH LAUNCH ANGLE AND ROTOCHUTE ORIENTATION

	Rotochute			Linear Error (ft)			Angular Error (deg-min)		
Launch Angle (deg)	Blade Orientation	Time to full opening (ms)(avg.)	No. of Observations	Spacing Distance Average	Standard Deviation	Standard Deviation from 350 ft	Trajectory Photo track to impact track	Navigation Photo track to reported track	Total reported track to impact track
30	Red	130	17	333.3	19.6	24.60		Not available	
30	White	145	16	337.5	27.0	29.88			
45	Red	136	23	338.0	34.0	35.99	3-44	5-6	7-47
45	White	197	24	346.5	16.3	16.65	4-22	2-11	5-4
70	Red	153	22	337.5	18.7	22.54	6-6	4-56	6-32
70	Blue	165	17	353.0	16.8	16.97	3-40	2-0	2-40
70	Pink	245	20	338.6	29.0	31.59	1-15	1-22	2-37
70	White	253	24	347.7	26.0	26.22	3-52	2-34	3-41
90	Red	209	16	357.0	24.0	25.22	3-26	2-51	2-17
90	White	305	16	347.6	23.8	24.0	3-50	1-10	4-40

TABLE VIII

AVERAGE ANGULAR ERROR CORRELATION FOR LAUNCH ANGLE AND ROTOCHUTE ORIENTATION

Launching Chute Angle (deg)	Rotochute Blade Orientation	Trajectory error from photo track to impact track (deg-min)	Navigation error reported track and photo track (deg-min)	Total error reported track to impact track (deg-min)
70	Red	6-6	4-56	6-32
70	White	3-52	2-34	3-41
70	Blue	3-40	2-40	2-0
70	Pink	1-15	1-22	2-37
45	Red	3-44	5-6	7-47
45	White	4-22	2-11	5-4
90	Red	3-26	2-51	2-17
90	White	3-50	1-10	4-40

In table VII, the time between sonobuoy ejection and full rotochute blade opening is compared with the resultant errors for all combinations of launch angle and rotochute orientation. There does not appear to be any correlation of these combinations with the time rate of full blade opening that could indicate any definitive effect on the values for placement accuracy. However, the combination of the 70-degree angle and blue orientation presents the best results with a standard deviation of 16.80 feet on the linear error and a total angular error of 2 degrees-40 minutes with a below average blade opening time of 165 milliseconds.

DISCUSSION OF THE TRAJECTORY

The action of the sonobuoy during the first half second after ejection determines largely whether or not a good drop pattern is obtained, and primary study is indicated here.

In all drops except those from the 90-degree angle, the rotochute end of the sonobuoy during emergence inclines toward the center of the aircraft and the blades start to rotate before the sonobuoy is completely ejected. It is believed that the tendency of the sonobuoy to incline when launched at lesser angles is due to faster opening of the blades and a longer time spent by the blades in the aircraft slip stream whose flow is toward the aircraft center line.

In the 90-degree launching position the sonobuoy is about half ejected before the first blade opens and the rest of the blades do not open until they have passed through the slipstream.

As the sonobuoys are ejected, they level off and their longitudinal axes may remain parallel to or point to the left or right of the longitudinal axis of the aircraft. This attitude is a reflection of the timing and rate of opening of the blades. Thus, if all blades open early, the sonobuoy will turn to the port side of the aircraft. Observations show approximately 20 percent of all sonobuoys lead to the left, 33 percent parallel to the center and the remainder to the right of the aircraft horizontal center line. Two cases were noted in which the longitudinal axis of the sonobuoy turned at right angles to the longitudinal axis of the airplane. In these cases the time period between sonobuoy ejection and impact was approximately 300 milliseconds less than that of the others. Obviously, a shorter trajectory can be inferred.

As the sonobuoy emerges from the aircraft, certain anamolies are observed. As the first blade opens the rotochute assembly begins to rotate and appears to tilt with respect to the longitudinal axis of the sonobuoy. The other blades open as their leading edges are in turn presented to the slip stream. The rotochute assembly accelerates very rapidly as it nears full opening to some intermediate value, decelerates and speeds up again. This action appears to occur with abrupt changes in attitude and rate of spin of the sonobuoy body and appears to cause variations in the rate of descent. These factors and evidence of wear in the rotochute thrust bearing inferentially prove that the bearing seizes the hub of the rotochute cap with a consequently increased transfer of torque to increase the rotational speed of the sonobuoy body.

When most of its kinetic forward motion has been arrested, the sonobuoy tends to assume more of a vertical attitude with a consequent reduction in the speed of rotochute rotation due to the decreased work required of the blades. However, the rpm of the sonobuoy itself does not abate.

ROTATION OF THE SONOBUOY IN DESCENT

In the descent of the sonobuoy there are four distinct movements, none of which appears paramount. First, as the sonobuoy drops, it oscillates in pitch as its attitude changes from rotochute cap down to cap uppermost. Second, the sonobuoy cap and bottom revolve rapidly in circles a few inches in diameter around an axis drawn through the center of gravity. Third, the center of gravity point of the sonobuoy appears to rotate in an approximate four foot circle while both ends describe their separate arcs. Fourth, the entire system travels downward in a sort of helical path. During descent, the rotational speed of the rotochute varies, and the increase in rotational speed of the body of the sonobuoy is not uniform. The rate of descent also changes and the trajectory may be displaced laterally. From the above it may be deduced that seizing of the rotochute on the hub of the sonobuoy occurs repeatedly during descent and is responsible in part for the lateral action described.

A careful study of all sonobuoys dropped did not indicate that any damage to the rotochute blades occurred during opening or descent. This would tend to prove that the blades and bumpers were mechanically strong enough to withstand the impact of opening, at least under the test conditions. No blade showed any cracks, bending or twisting. However, there was indication of damage to the rotochute bearings. The rotochute assembly is as shown in figure 14 with details of bolt and washer "W" in figures 15 and 16. The depression "A" in the washer fitted the boss "B" on the bolt, apparently for the purpose of allowing the washer to rotate on this boss. The blade mount "C" under load, thrusts against this washer. The bolt is staked into the cap "D" to prevent turning.

Thus when the blades of the rotochute had opened and were in operation, the blade mount "C" would use the washer "W" as a thrust bearing, the washer being held by the bolt head. Inspection after a drop sometimes showed that the depression "A" had increased in depth and also showed evidence of rotation and galling from the bolt head. Markings on the washer face "F" indicated that the washer under load had apparently bent upward, causing rotation marks attributed to the hexagon corners of the bolt head to be imposed on the surface "F". Observation also showed considerable wear on surface "E" of the washer caused by the rubbing of the blade mount. It is evident that the washer did have irregular periods of rotation, sometimes none and probably not much at any time, being seemingly held rather well by the bolt head. It is inferred from the above that sufficient heat was generated as the blade mount rotated against the washer to cause the two parts to seize momentarily. This seizure would cause momentary rotation of the washer against the bolt head and subsequent slowing of rotochute blades with the consequent rotational acceleration of the sonobuoy. As the blades slowed, an increase in the speed of descent of the sonobuoy would occur. This increased speed of descent and thus greater torque on the blades would break the "weld" of blade mount and washer, and permit the blades to accelerate and reduce the speed of descent. The cycle would then be repeated. No consistent sequence or timing of this cycle was observed. Examination of the washers also revealed that the greatest concentration of wear on the bolt side (face F) and the greatest wear on the blade mount side (face E) were diametrically opposite. This could indicate that the rotational plane of the blade mount was not always normal to the longitudinal axis of the sonobuoy. It can be inferred that the above may occur from any combination of the following causes:

a. Normal wind tending to tilt sonobuoy during descent

b. Imbalance of blades

c. Imbalance of rotochute assembly

d. Rocking due to yawing of the buoy or rotochute during descent

e. Poor bearing - that is, if the galling should occur once there would be a tendency for it to recur at the same point, causing progressive deterioration.

In summary it was observed that during descent:

a. The rpm of the rotochute varied, and some of the changes appeared to be abrupt.

b. The rpm of the sonobuoy increased by increments at various times.

c. There was lateral displacement of the trajectory.

d. The speed of descent varied from 45 to 96 feet per second.

e. All of the above phenomena appear to be random and irregular but are probably directly related to each other.

Hence, it is deduced that repetitive seizing of the rotochute mount and the sonobuoy hub occurs often and causes fluctuation in the rate of descent.

Appendix A-1 contains the compilation of all the basic data from the flight tests conducted at NAS, Lakehurst, tables A-1 through A-13. Included are the corresponding values adjusted for all discrepancies from the established test criteria.

Figures A-1 through A-15 illustrate the frequency distribution of all of the spacings with respect to the angle of launch and sonobuoy orientation in the launching chute.

ACKNOWLEDGEMENT

Personnel of the U. S. Naval Air Station, Lakehurst, New Jersey rendered valuable assistance during performance of the flight test program made there. The Public Works Department provided services for surveying and marking the grid pattern on the drop site. The Operations Department integrated the project aircraft flight schedule into the Station's daily requirements so that no delays were encountered.

REFERENCES

(a) BUAER ltr Aer-AV-3413-W/75 of 29 Jan 1959
(b) VX-1 ltr code 70, ser 0185 of 14 Aug 1958
(c) VX-1 ltr code 70, ser 0256 of 26 Nov 1958

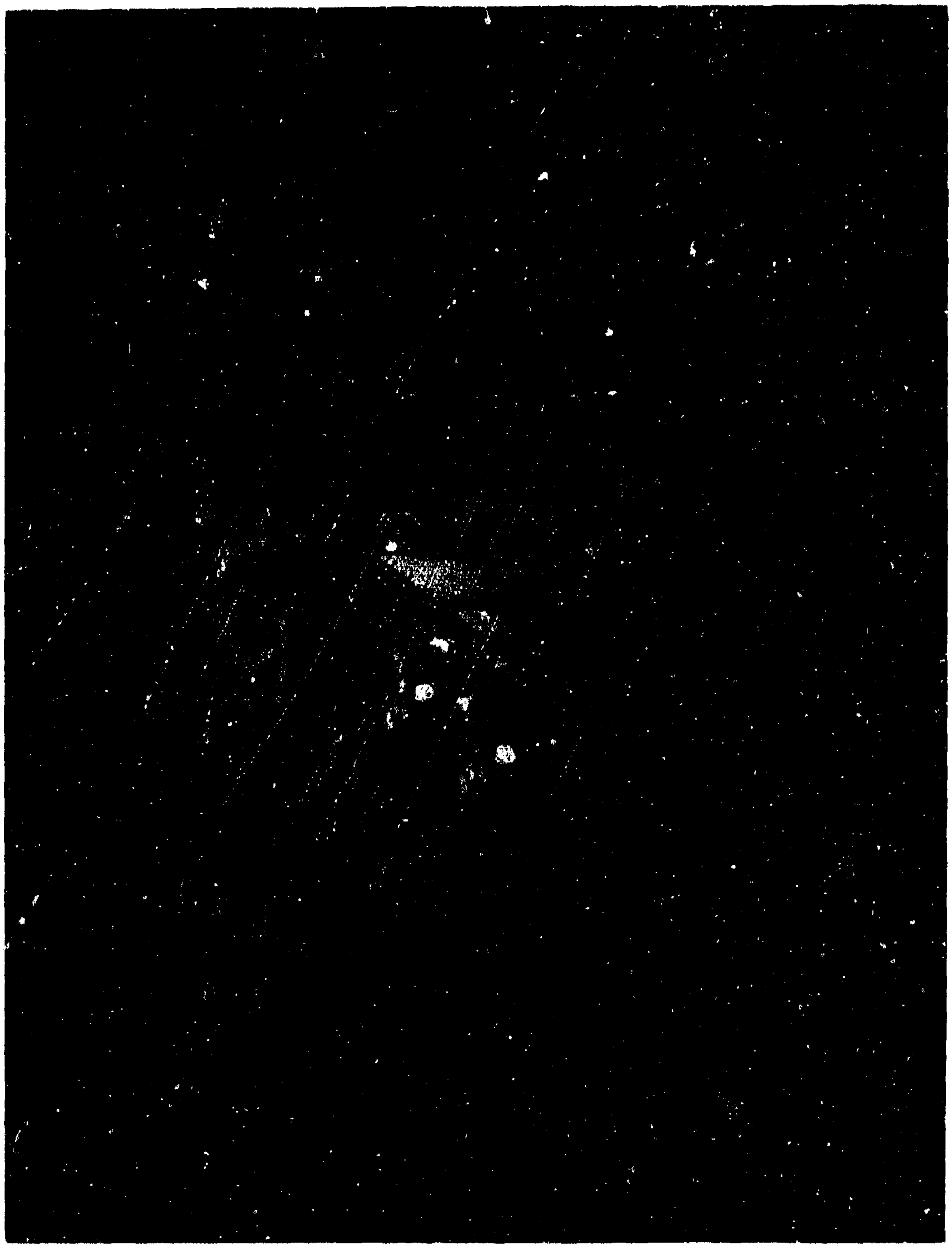


FIGURE 1 - Installation of Experimental Launching Equipment in P2V-5F Aircraft Launching Chutes at 70 and 45 Degree Angles

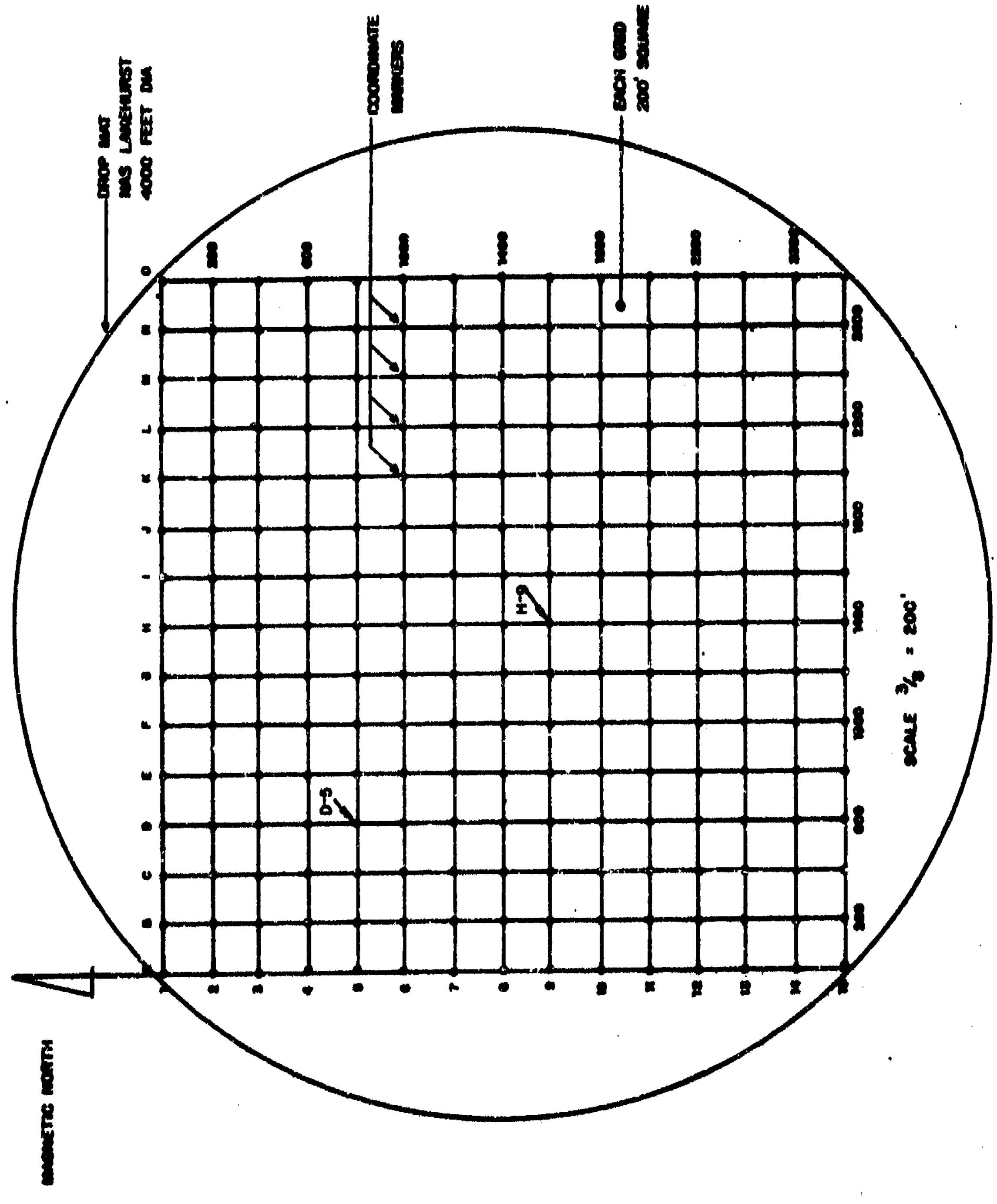


FIGURE 2 - Grid Layout on Mat 4, NAS Lakehurst

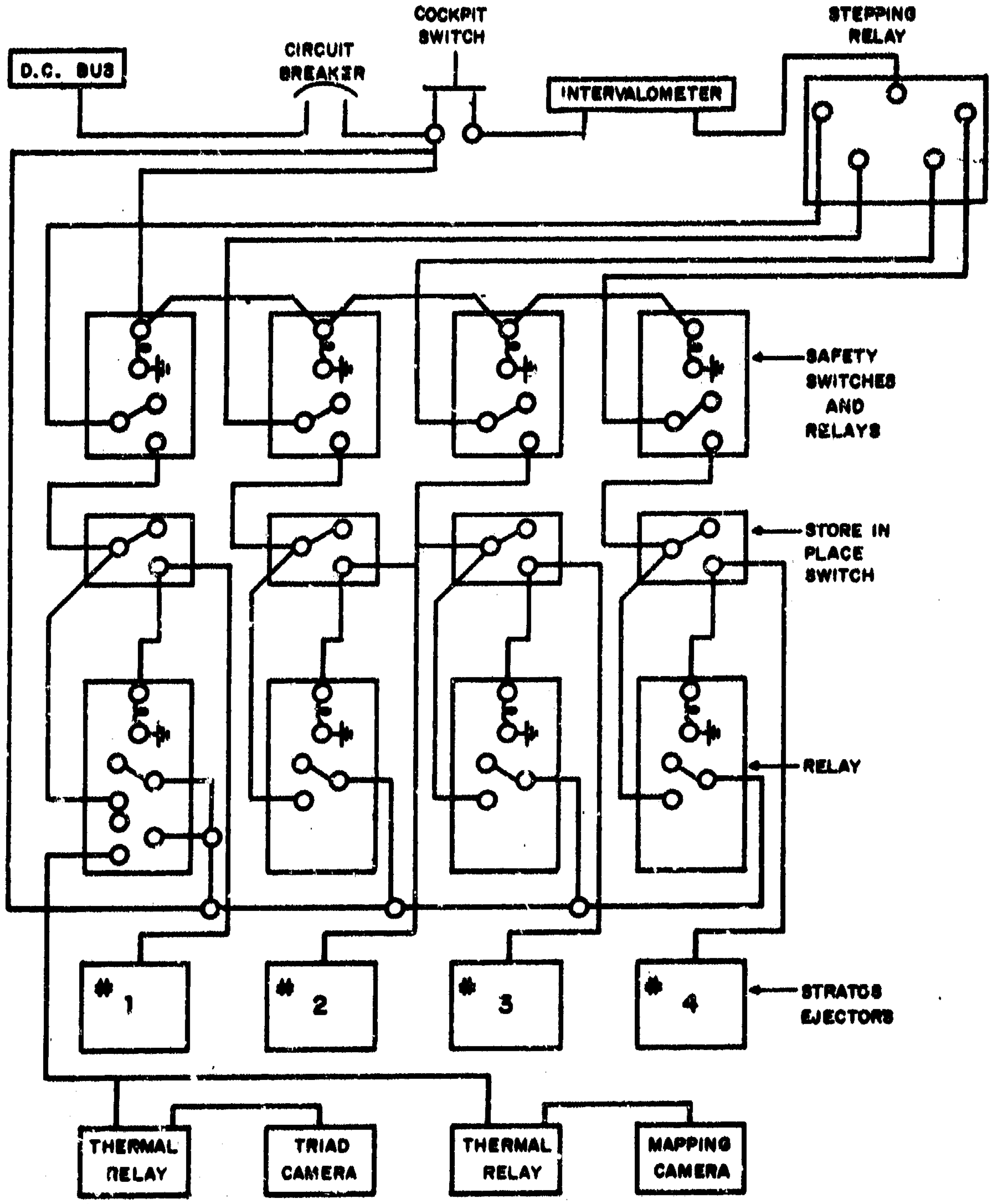


FIGURE 3 - Schematic Electrical Diagram, Sonobuoy Launching System in P2V-5F Aircraft

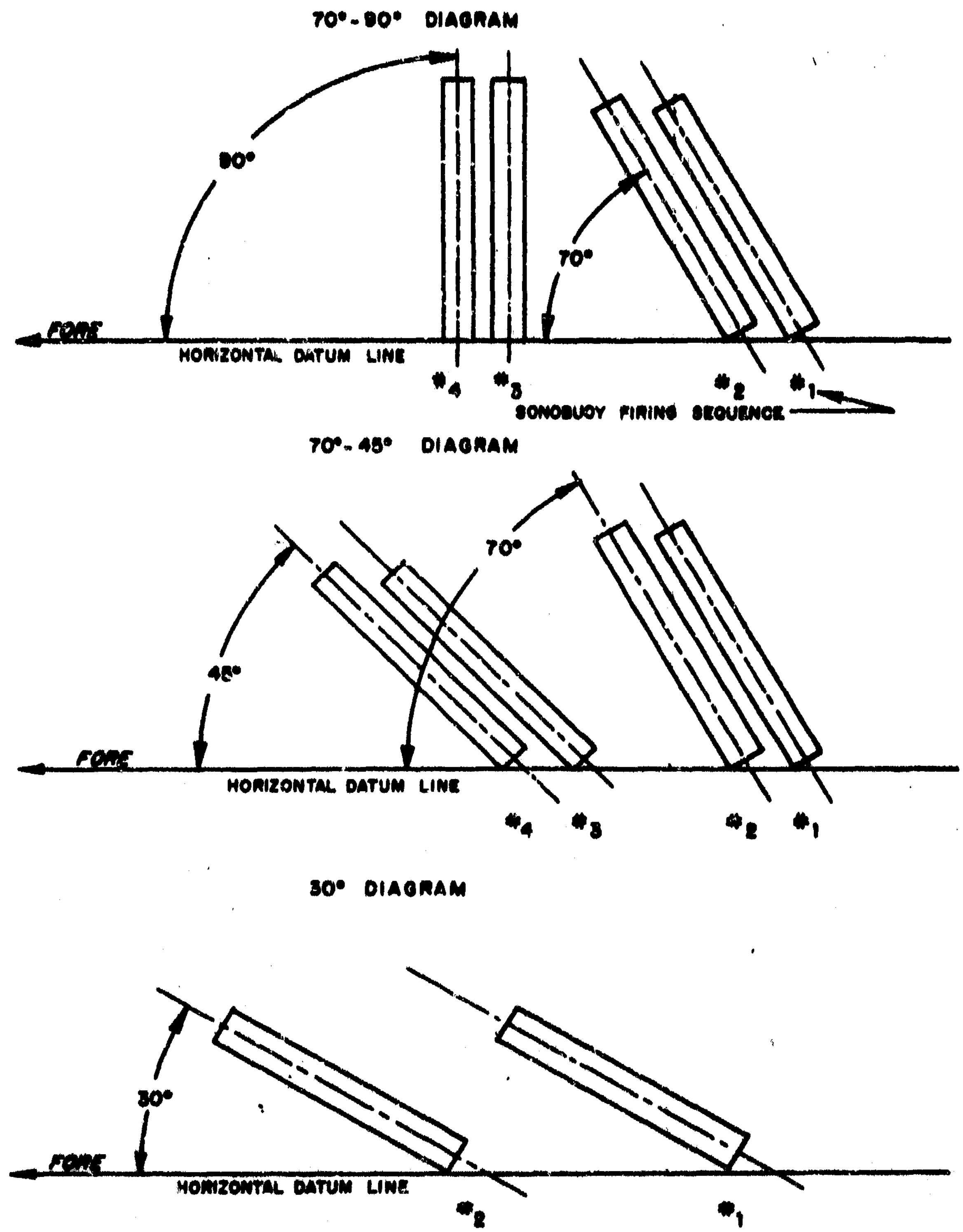


FIGURE 4 - Schematic Diagram of Launching Tube Configurations

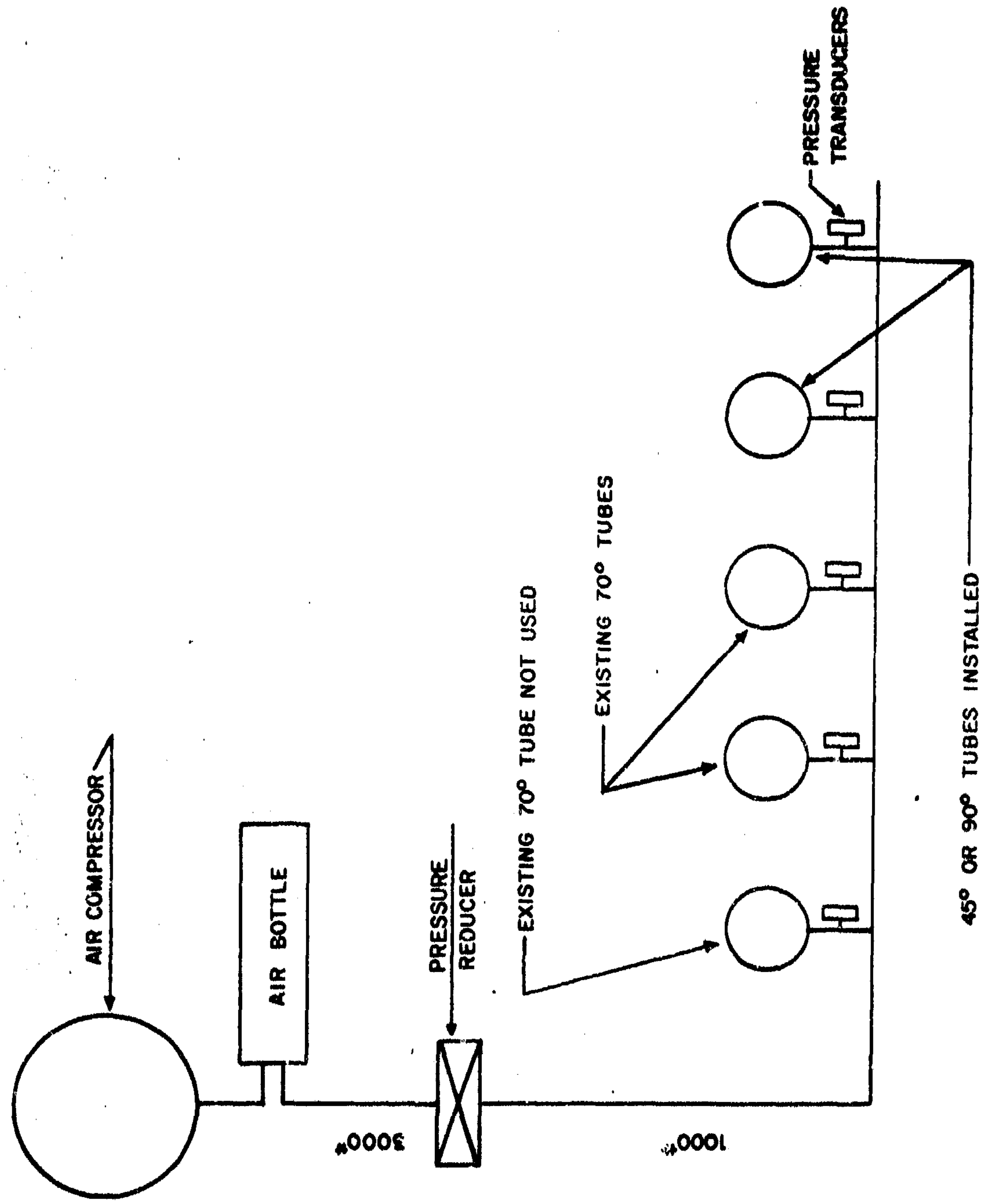


FIGURE 5 - Schematic Pneumatic Diagram

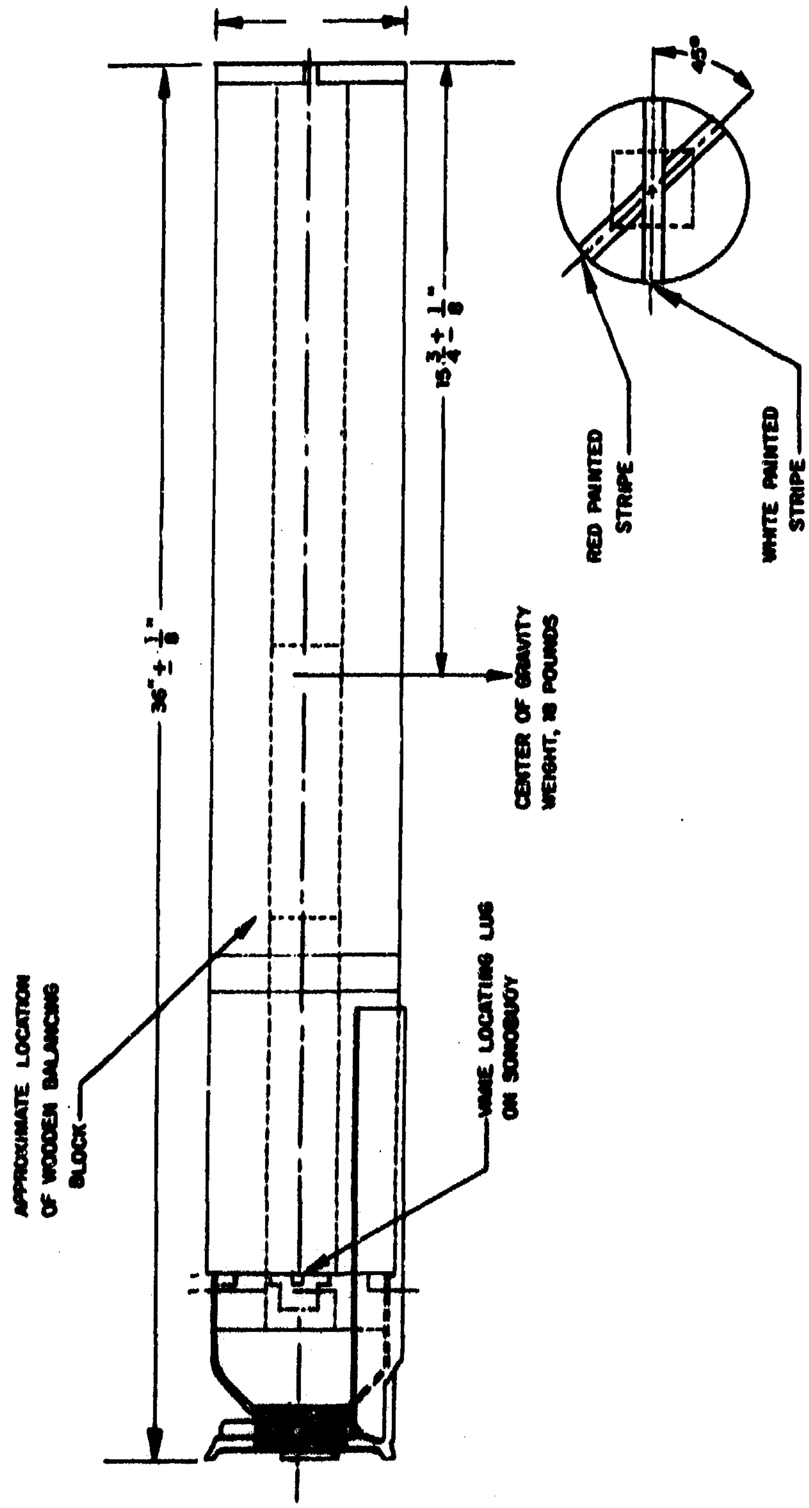


FIGURE 6 - Drawing of Dummy Sonobuoy

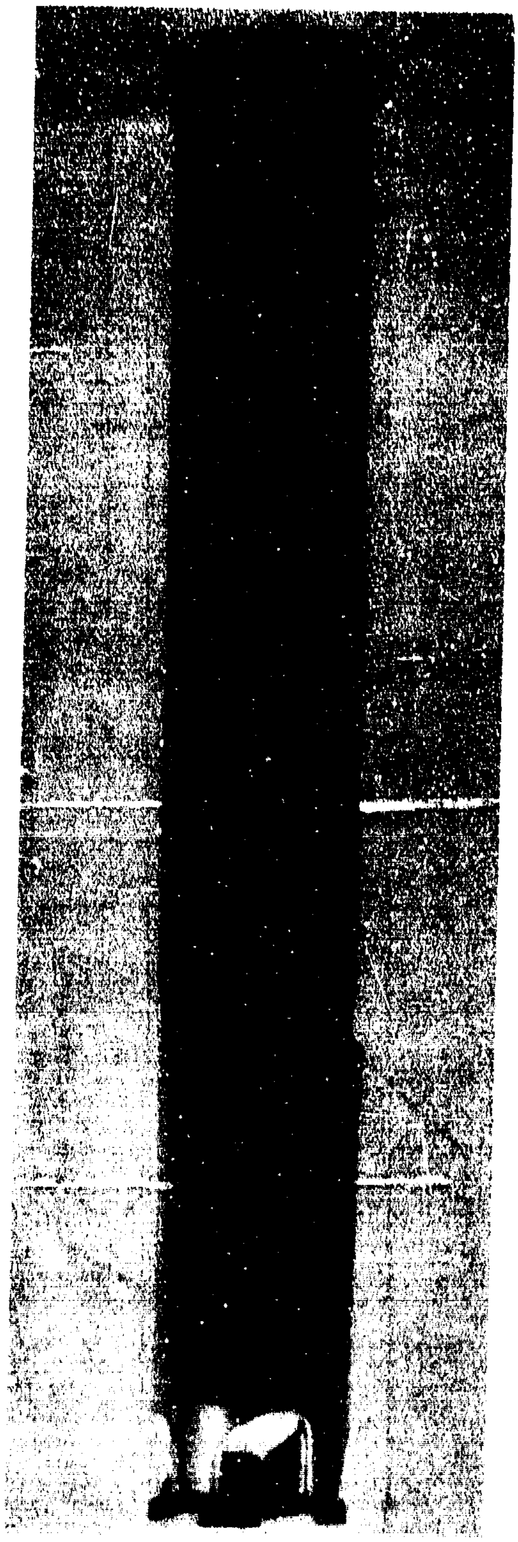


FIGURE 7 - Photo of Dummy Sonobuoy

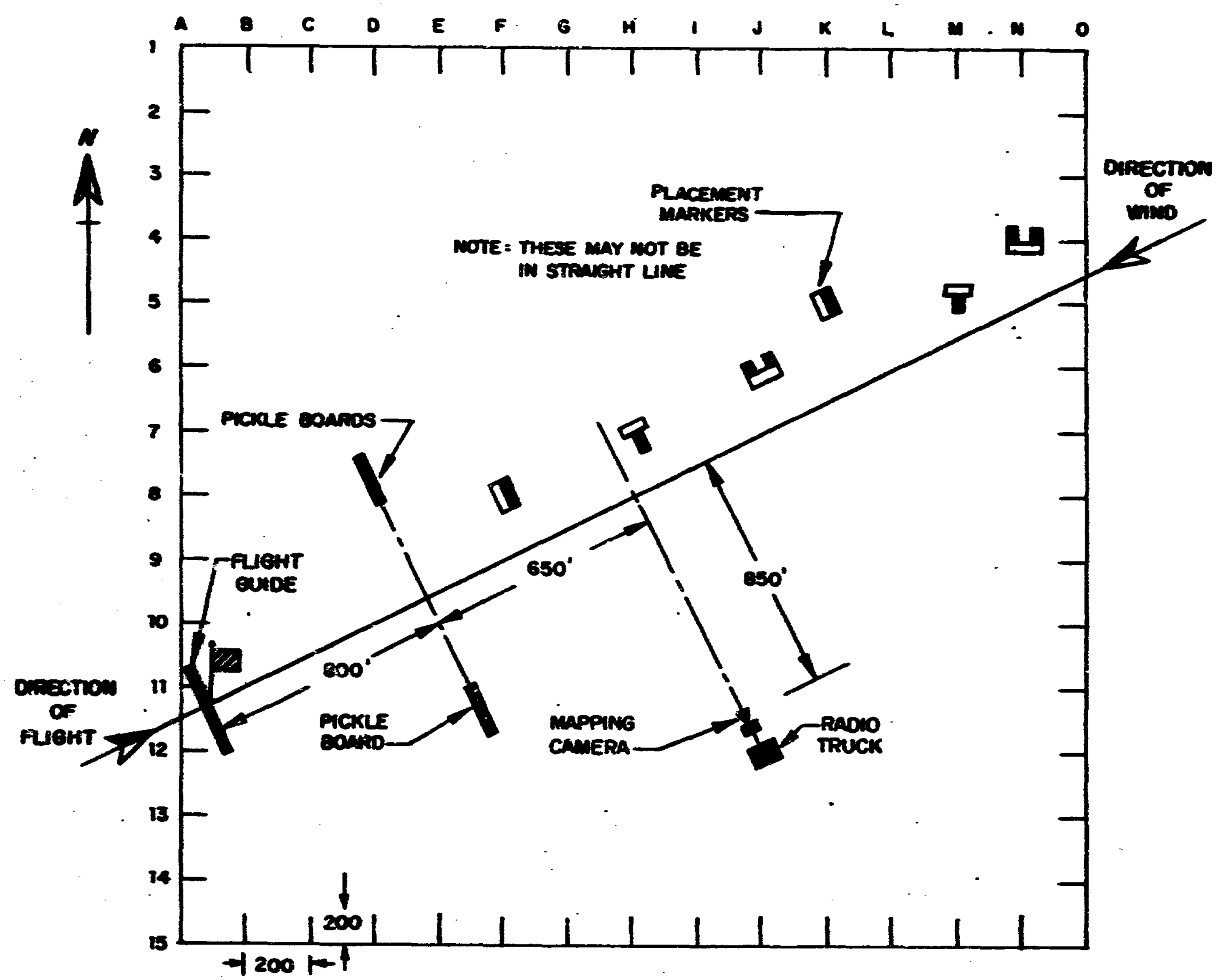


FIGURE 8 - Sample Flight Diagram Showing Flight Placement Markers

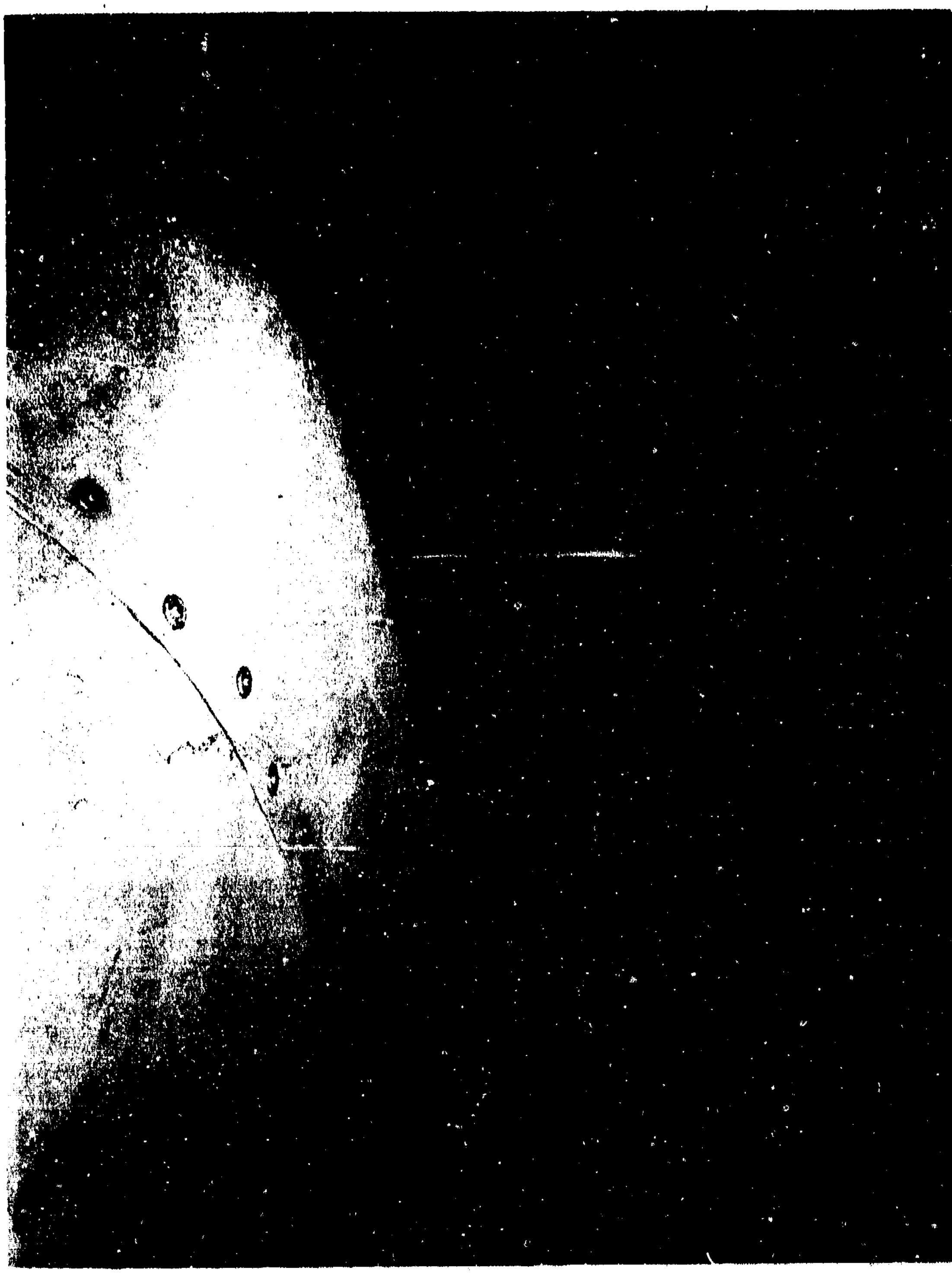


FIGURE 9 - Fuselage Camera Installation (Photo CAD 7544(L))

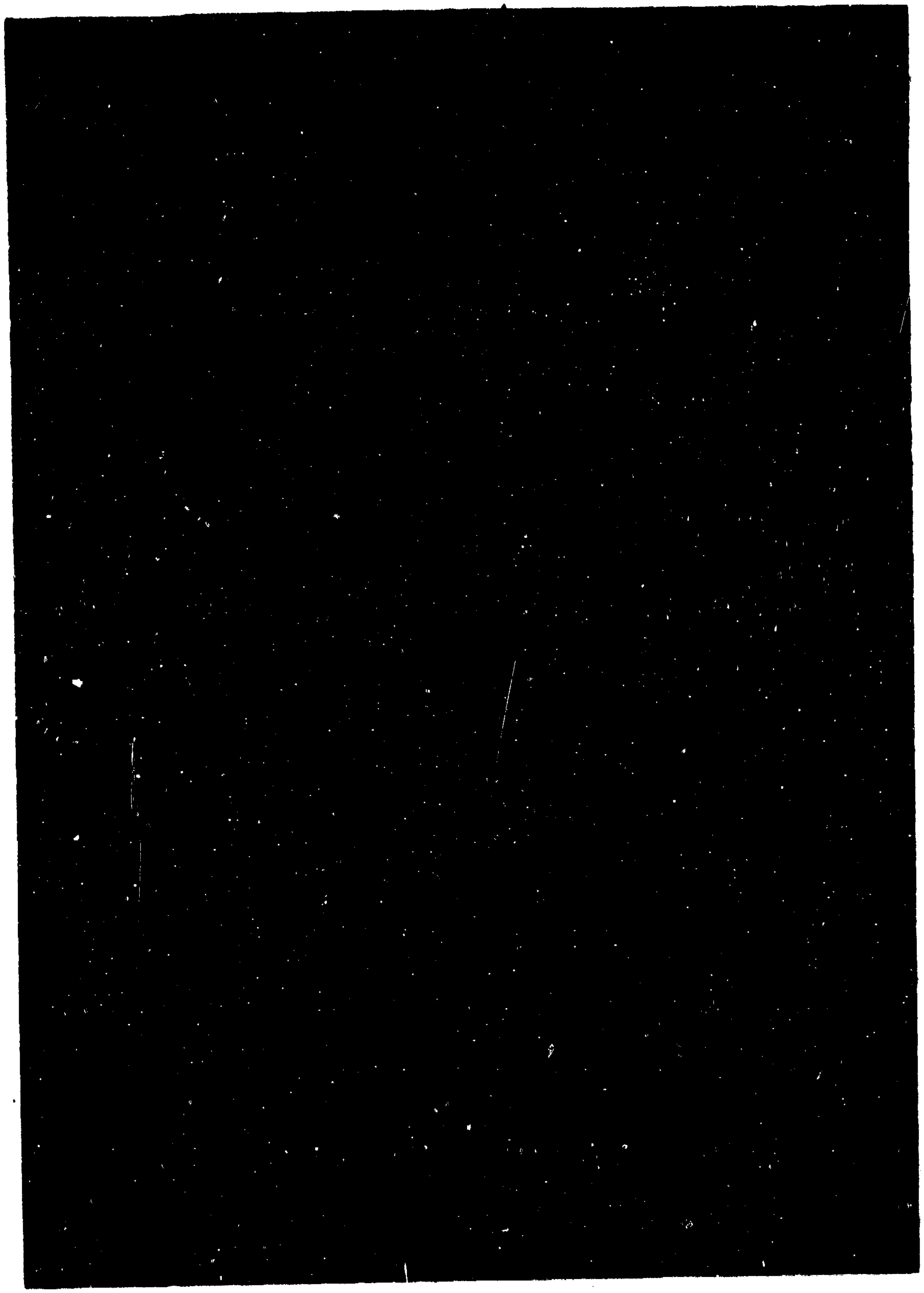
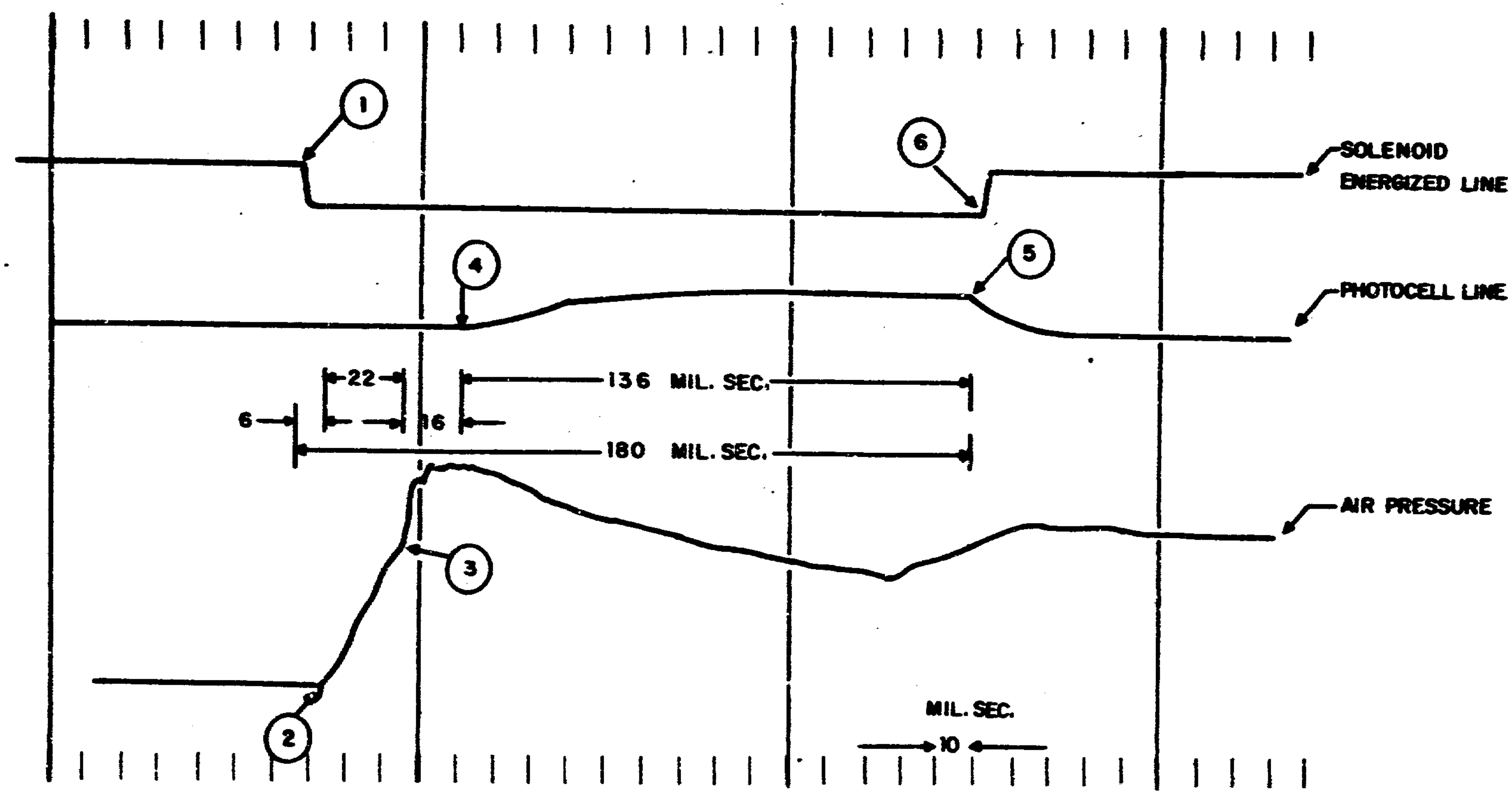


FIGURE 10 - Recording Oscillograph Installation (Photo CAD 7546(L))



POINT (1) OF PULSE TO SOLENCID
" (2) OF OPENING OF SOLENOID
" (3) OF FULL AIR PRESSURE IMPOSED ON PISTON
" (4) OF INITIAL MOVEMENT OF STORE
" (5) OF EJECTION OF STORE
" (6) SOLENOID DEENERGIZED

FIGURE 11 - Oscillograph Record Sample Run B-2

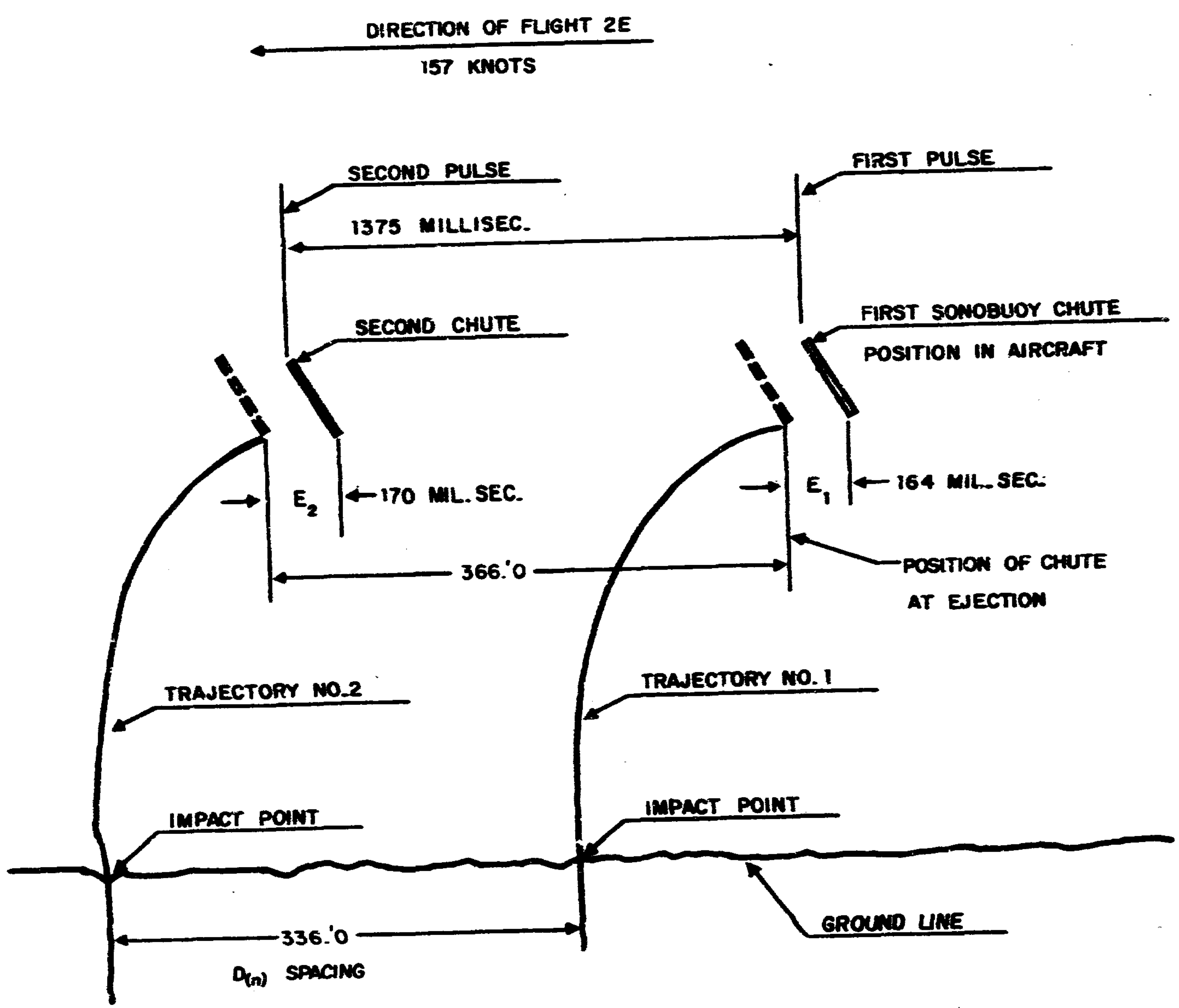


FIGURE 12 - Illustration of Trajectory Effect on Spacing

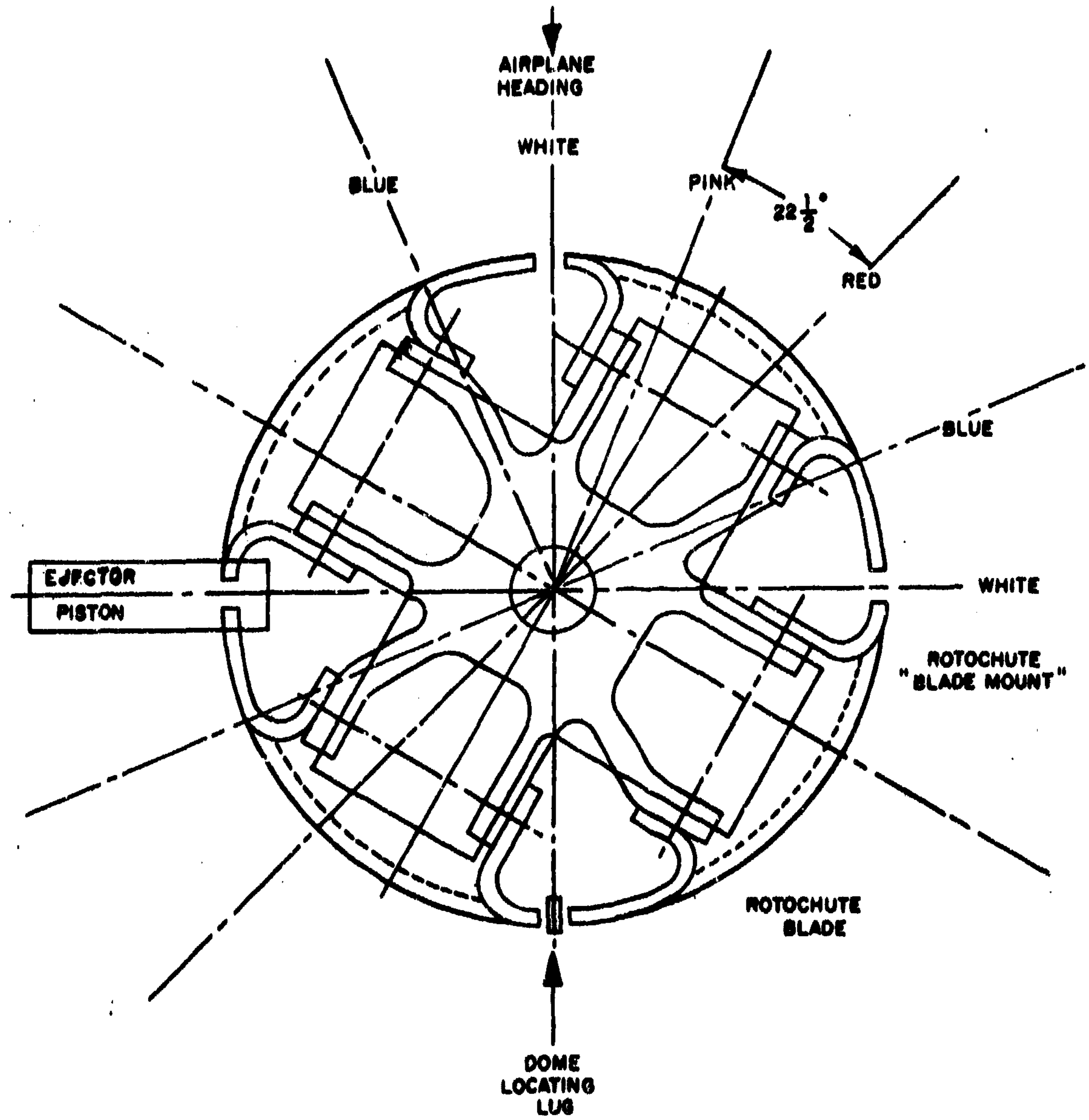


FIGURE 13 - Rotochute Blade Orientation -
View Looking Down Launcher Chute

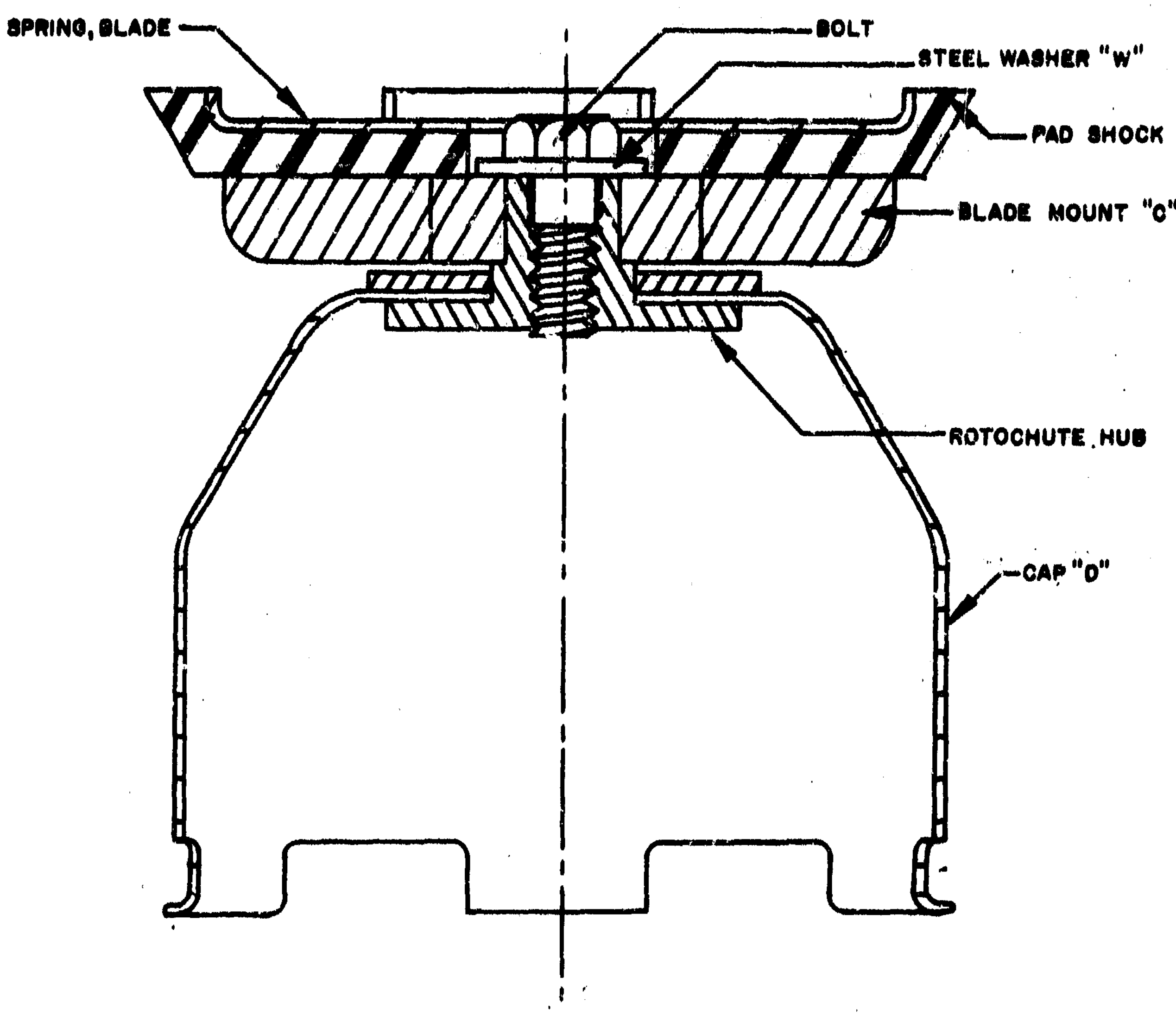


FIGURE 14 - Sonobuoy Rotochute Assembly

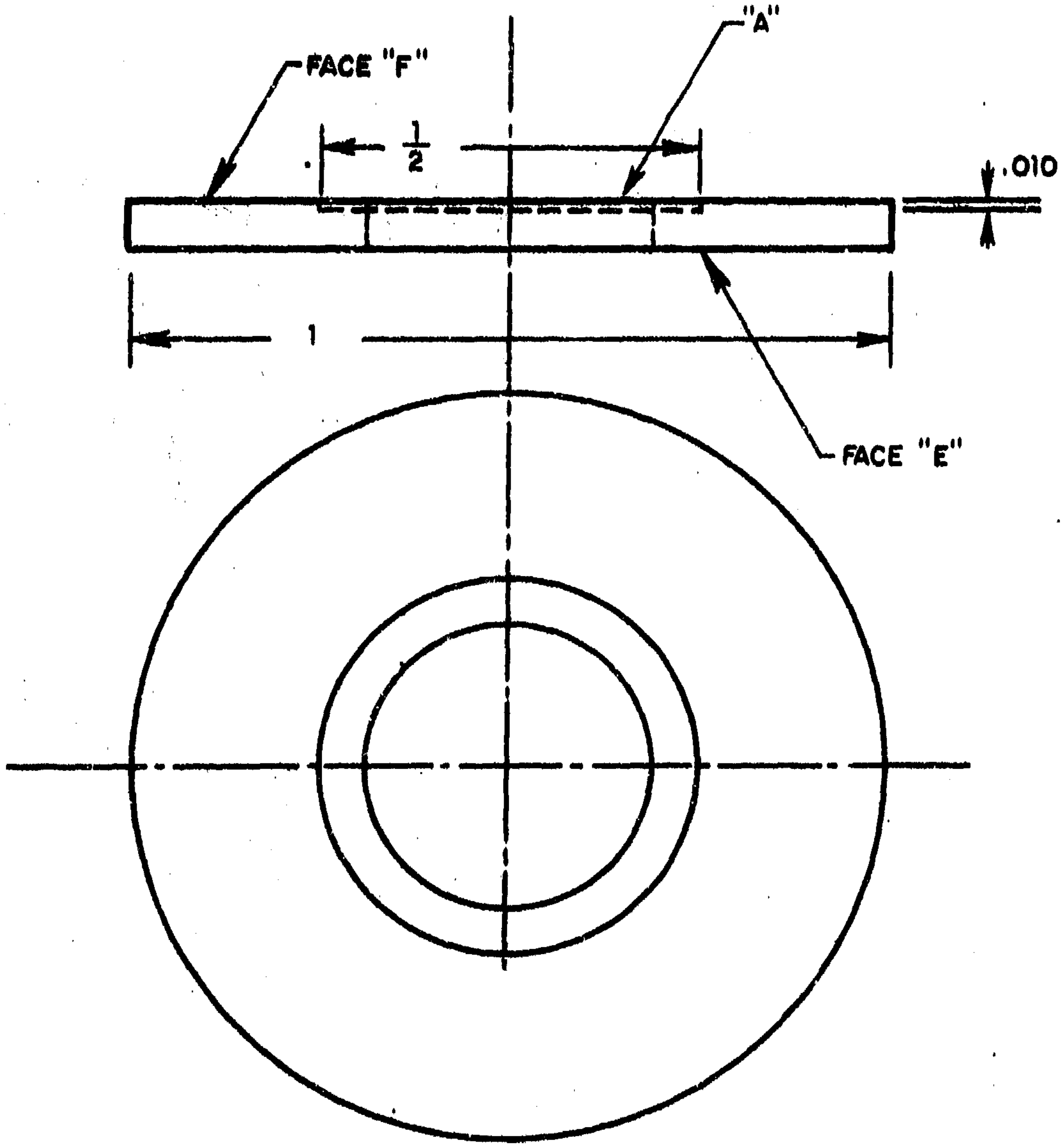


FIGURE 15 - Rotochute Washer

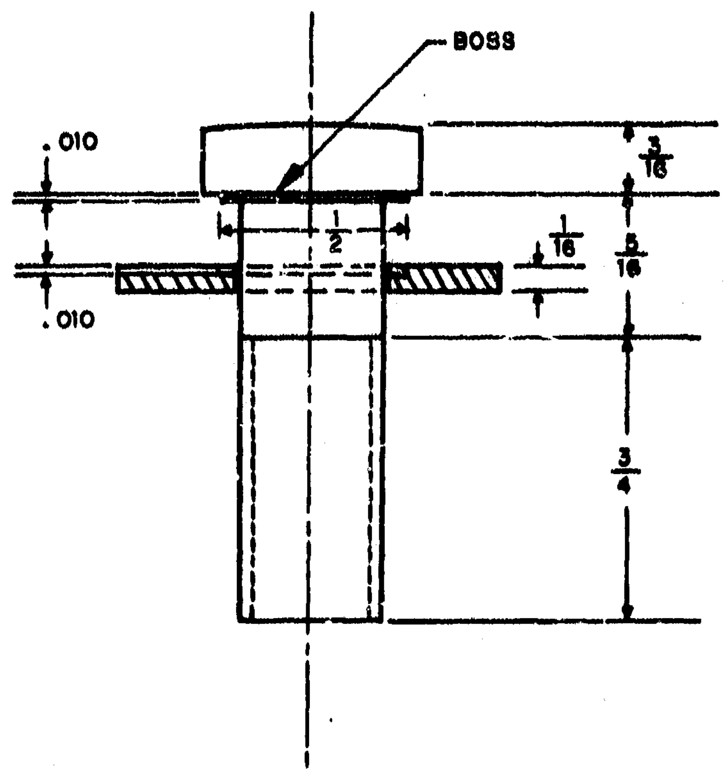


FIGURE 16 - Rotochute Bolt and Washer

APPENDIX A-1

BASIC DATA

TABLE A-I

SUMMARY OF SPACING RESULTS

Launching Chute Angle (deg)	Rotochute Blade Orientation	Nominal Aircraft Altitude (ft)	Nominal Aircraft Speed (kt)	No. of Pairs of Sonobuoys Dropped	Sonobuoys as Dropped (ft): Average Measured Spacing Between Sonobuoys	Sonobuoys as Dropped (ft): Around Average Drop Distance: Standard Deviation	Sonobuoys as Dropped (ft): Around Average Drop Distance: Arithmetical Deviation	Sonobuoys as Dropped (ft): Desired Spacing Between Sonobuoys	Sonobuoys as Dropped (ft): Around Average Drop Distance: Standard Deviation	Sonobuoys as Dropped (ft): Around Average Drop Distance: Arithmetical Deviation	Corrected for Speed, Altitude, Intervalometer (ft): Average Distance Between Sonobuoys	Corrected for Speed, Altitude, Intervalometer (ft): Around Average Drop Distance: Standard Deviation	Corrected for Speed, Altitude, Intervalometer (ft): Around Average Drop Distance: Arithmetical Deviation	Corrected for Speed, Altitude, Intervalometer (ft): Desired Distance Between Sonobuoys	Corrected for Speed, Altitude, Intervalometer (ft): Around Average Drop Distance: Standard Deviation	Corrected for Speed, Altitude, Intervalometer (ft): Around Average Drop Distance: Arithmetical Deviation
30	White	500	150	16	335.9	25.14	18.85	350	28.84	25.75	337.5	27.08	22.25	350	29.88	25.50
30	Red	500	150	17	333.8	19.42	16.56	350	25.28	18.53	333.3	19.60	16.71	350	24.60	19.53
45	White	500	150	24	350.5	22.15	16.38	350	22.16	16.50	346.5	16.29	13.10	350	16.65	12.70
45	Red	500	150	23	341.0	34.19	26.22	350	35.60	27.34	338.0	34.00	26.65	350	35.99	28.30
70	White	500	150	24	351.2	22.86	17.08	350	22.91	17.30	347.7	26.07	20.62	350	26.22	20.96
70	Red	500	150	22	341.5	22.40	17.05	350	23.98	18.86	337.5	18.76	14.14	350	22.54	16.80
70	Pink	500	150	20	349.7	25.34	19.02	350	25.34	19.05	338.6	29.46	22.80	350	31.59	24.10
70	Blue	500	150	17	361.0	11.94	9.88	350	16.39	13.10	353.0	16.83	14.00	350	16.97	14.00
90	White	500	150	16	259.9	24.66	19.61	350	27.40	21.75	347.6	23.80	20.76	350	24.00	20.50
90	Red	500	150	16	370.0	23.34	20.20	350	31.36	25.56	357.0	24.25	19.06	350	25.22	21.44
45	Red	1000	200	10	368.4	16.77	14.48	350	24.86	19.00	354.4	15.84	13.48	350	21.41	15.60
70	Red	1000	200	10	357.8	14.65	11.90	350	16.58	13.80	353.5	16.71	12.90	350	15.44	12.90
30	All	500	150	33	334.8	28.05	17.45	350	27.06	21.03	335.3	23.65	18.97	350	27.85	22.73
45	All	All	All	57	349.7	28.74	21.37	350	28.54	21.18	346.4	26.49	19.69	350	26.82	19.51
70	All	All	All	93	351.2	22.14	16.99	350	21.98	16.92	344.8	23.88	18.14	350	24.15	18.65
90	All	500	150	32	366.5	25.43	20.92	350	31.01	24.73	353.6	24.87	20.57	350	25.11	21.45
All	All	All	All	All	-	-	-	-	-	-	344.9	25.06	19.64	350	22.33	19.80

TABLE A-II

DETAILED DATA 30 DEGREE LAUNCHING ANGLE WHITE ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
1E	1-2	340	349	12.5	090	460	088	147	1375
1G	1-2	322	324	11.0	080	525	093	149	1380
1I	1-2	327	331	13.0	070	540	093	148	1380
1K	1-2	323	330	12.0	104	500	097	147	1380
1M	1-2	321	335	11.0	096	460	099	146	1363
1O	1-2	331	350	13.0	102	500	095	144	1367
2A	1-2	377	380	10.0	330	500	360	155	1329
2C	1-2	309	301	8.0	335	500	360	155	1371
2E	1-2	336	321	9.0	337	500	360	157	1375
2H	1-2	399	397	11.5	350	500	360	152	1370
2I	1-2	330	324	14.0	325	500	360	154	1369
3A	1-2	310	297	7.0	310	500	360	158	1373
3C	1-2	301	306	9.5	350	500	360	148	1370
3E	1-2	347	362	13.5	336	500	360	145	1370
3G	1-2	367	365	7.5	346	500	360	155	1345
4G	1-2	334	328	8.5	290	500	360	160	1320

As Measured	Corrected	
335.9	337.5	Average distance between impact points
25.14	27.08	Standard deviation around average distance
18.85	22.25	Arithmetical deviation around average distance
350.0	350.0	Desired distance between impact points
28.84	29.88	Standard deviation around desired distance
25.75	25.50	Arithmetical deviation around desired distance

TABLE A-III

DETAILED DATA 30 DEGREE LAUNCHING ANGLE RED ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
1F	1-2	344	352	11.2	094	480	092	148	1370
1H	1-2	305	306	12.0	070	475	093	149	1360
1J	1-2	313	333	12.0	100	580	094	141	1380
1L	1-2	351	338	8.0	103	540	098	157	1370
1N	1-2	332	339	12.2	092	500	096	149	1362
2B	1-2	315	311	12.0	335	500	360	153	1369
2D	1-2	344	341	11.0	000	500	360	152	1377
2F	1-2	292	295	8.0	350	500	360	149	1375
2J	1-2	327	318	8.0	350	500	360	155	1371
3B	1-2	212	307	12.0	313	500	360	154	1367
3D	1-2	349	354	13.0	354	500	360	149	1370
3F	1-2	357	360	11.5	353	500	360	151	1360
3J	1-2	350	358	8.2	351	500	360	149	1361
4B	1-2	335	336	8.0	312	500	360	152	1352
4D	1-2	362	355	9.0	318	500	360	156	1353
4F	1-2	345	342	11.0	290	500	360	154	1358
4H	1-2	342	321	5.5	280	500	360	162	1365

As Measured	Corrected	
333.8	333.3	Average distance between impact points
19.42	19.64	Standard deviation around average distance
16.56	16.71	Arithmetical deviation around average distance
350.0	350.0	Desired distance between impact points
25.28	24.60	Standard deviation around desired distance
18.53	19.53	Arithmetical deviation around desired distance

TABLE A-IV

DETAILED DATA 45 DEGREE LAUNCHING ANGLE WHITE ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)	Time For Sonobuoy Ejection (ms) 1st Unit	Time For Sonobuoy Ejection (ms) 2nd Unit
A1	3-4	367	362	3.0	295	500	255	153	1376	187	190
A3	3-4	330	333	6.0	270	500	225	149	1370	181	210
A5	3-4	320	314	2.0	330	540	225	152	1376	185	190
A7	3-4	353	347	3.0	320	540	225	155	1363	182	184
A9	3-4	331	332	5.5	300	460	225	151	1364	181	184
B1	3-4	330	327	15.0	250	500	240	153	1372	172	193
B3	3-4	278	305	15.0	260	580	235	138	1369	185	192
B5	3-4	355	361	14.0	250	500	242	149	1364	181	194
B7	3-4	332	331	14.0	280	500	242	152	1366	178	188
B9	3-4	355	363	20.0	270	500	240	148	1363	180	203
C3	3-4	357	334	8.0	045	580	002	162	1363	179	181
C5	3-4	341	352	10.0	037	500	358	147	1367	-	-
C7	3-4	345	348	9.0	005	560	001	150	1369	180	182
C9	3-4	360	354	9.0	018	580	000	154	1366	191	181
D1	3-4	350	347	6.0	000	560	242	152	1371	-	196
D2	3-4	376	364	6.0	028	540	247	156	1369	182	208
D3	3-4	362	354	7.0	024	580	246	154	1371	186	204
D4	3-4	365	358	6.5	027	580	245	154	1367	182	182
D5	3-4	367	361	6.5	015	560	245	153	1369	181	184
D6	3-4	371	358	5.0	016	560	246	156	1369	180	196
D7	3-4	390	373	5.0	030	600	246	158	1368	183	205
D8	3-4	360	349	4.5	036	550	244	156	1366	185	181
D9	3-4	361	352	4.0	025	530	247	156	1364	187	182
D10	3-4	354	340	5.0	036	530	247	158	1365	178	183
		350.5	346.5	Average distance between impact points							
		22.15	16.29	Standard deviation around average distance							
		16.38	13.10	Arithmetical deviation around average distance							
		350.0	350.0	Desired distance between impact points							
		22.16	16.65	Standard deviation around desired distance							
		16.50	12.70	Arithmetical deviation around desired distance							

TABLE A - V

DETAILED DATA 45 DEGREE LAUNCHING ANGLE RED ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)	Time For Sonobuoy Ejection (ms) 1st Unit	Time For Sonobuoy Ejection (ms) 2nd Unit
A2	3-4	335	327	4.0	297	500	218	155	1372	180	185
A4	3-4	331	330	5.5	290	500	223	153	1367	181	198
A6	3-4	334	338	6.0	260	560	227	149	1368	180	184
A8	3-4	310	296	6.0	000	440	229	159	1364	180	183
B2	3-4	302	295	14.0	250	500	238	154	1375	180	182
B4	3-4	334	332	12.0	260	500	238	152	1366	174	181
B6	3-4	369	365	12.0	265	500	238	153	1365	179	185
B8	3-4	256	248	16.0	270	500	240	156	1368	180	182
B10	3-4	372	367	15.0	250	500	244	154	1366	180	190
C2	3-4	377	370	10.0	036	460	356	154	1371	180	177
C4	3-4	286	300	6.0	036	560	355	145	1367	180	181
C6	3-4	352	348	8.0	352	500	358	153	1368	180	182
C8	3-4	346	336	10.0	055	500	000	155	1372	182	180
E1	3-4	291	299	10.0	230	600	300	148	1364	182	184
E2	3-4	405	385	15.0	220	600	306	160	1360	183	186
E3	3-4	372	373	10.0	245	600	306	151	1364	183	183
E4	3-4	385	366	8.0	250	600	302	151	1365	-	-
E5	3-4	344	341	9.0	230	600	302	153	1363	181	189
E6	3-4	340	325	8.0	226	600	300	159	1363	183	185
E7	3-4	378	388	11.0	250	500	298	148	1364	181	186
E8	3-4	328	326	9.0	247	600	300	153	1365	180	183
E9	3-4	348	348	9.0	234	600	300	152	1389	180	189
E10	3-4	346	356	11.0	247	600	300	148	1363	133	138

As Measured	Corrected	
341.0	338.0	Average distance between impact points
34.19	34.0	Standard deviation around average distance
26.22	26.65	Arithmetical deviation around average distance
350.0	350.0	Desired distance between impact points
35.60	35.99	Standard deviation around desired distance
27.34	28.30	Arithmetical deviation around desired distance

TABLE A-VI

DETAILED DATA 70 DEGREE LAUNCHING ANGLE WHITE ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
A1	1-2	350	345	3.0	295	500	255	153	1376
A3	1-2	325	329	6.0	270	500	225	149	1369
A5	1-2	326	322	2.0	330	540	225	152	1376
A7	1-2	354	347	3.0	320	540	225	155	1363
A9	1-2	325	326	5.5	300	460	225	151	1368
B1	1-2	338	334	15.0	250	500	240	153	1373
B3	1-2	371	408	15.0	260	580	235	138	1370
B5	1-2	289	294	14.0	250	500	242	149	1369
B7	1-2	389	389	14.0	280	500	242	152	1364
B9	1-2	384	392	20.0	270	500	240	148	1366
C1	1-2	352	343	10.0	040	500	000	155	1368
C3	1-2	344	313	8.0	045	580	002	162	1365
C5	1-2	352	363	10.0	037	500	358	147	1357
C7	1-2	318	320	9.0	005	560	001	150	1367
C9	1-2	365	359	9.0	018	580	000	154	1368
D1	1-2	368	365	6.0	000	560	242	152	1374
D2	1-2	351	340	6.0	028	540	247	156	1369
D3	1-2	379	370	7.0	024	580	246	154	1372
D4	1-2	362	354	6.5	027	580	245	154	1370
D5	1-2	357	352	6.5	015	560	245	153	1372
D6	1-2	356	345	5.0	016	560	246	156	1370
D7	1-2	349	334	5.0	030	600	246	158	1369
D9	1-2	382	372	4.0	025	530	247	156	1362
D10	1-2	343	328	5.0	036	530	247	158	1365

As Measured	Corrected	
351.2	347.7	Average distance between impact points
22.86	26.07	Standard deviation around average distance
17.08	20.62	Arithmetical deviation around average distance
350.0	350.0	Desired distance between impact points
22.91	26.22	Standard deviation around desired distance
17.30	20.96	Arithmetical deviation around desired distance

TABLE A-VII

DETAILED DATA 70 DEGREE LAUNCHING ANGLE RED ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
A2	1-2	344	325	4.0	297	500	218	155	1370
A4	1-2	347	343	5.5	290	500	223	153	1370
A6	1-2	329	334	6.0	260	560	227	149	1370
A8	1-2	333	319	6.0	000	440	229	159	1364
B2	1-2	307	300	14.0	250	500	238	154	1369
B6	1-2	336	333	12.0	265	500	238	153	1367
B8	1-2	378	368	16.0	270	500	240	156	1368
B10	1-2	346	341	15.0	250	500	244	154	1364
C2	1-2	368	359	10.0	036	480	356	154	1371
C4	1-2	335	350	6.0	036	560	355	145	1367
C6	1-2	344	342	8.0	352	500	358	153	1366
C8	1-2	351	342	10.0	055	500	000	155	1371
E1	1-2	322	329	10.0	230	600	300	148	1364
E2	1-2	369	350	15.0	220	600	306	160	1360
E3	1-2	339	341	10.0	245	600	306	151	1364
E4	1-2	334	335	8.0	250	600	302	151	1365
E5	1-2	371	367	9.0	230	600	302	153	1363
E6	1-2	368	351	8.0	226	600	300	159	1363
E7	1-2	281	288	11.0	250	500	298	148	1364
E8	1-2	335	332	9.0	247	600	300	153	1365
E9	1-2	359	352	9.0	234	600	300	152	1389
E10	1-2	317	324	11.0	247	600	300	148	1363
		341.5	337.5	Average distance between impact points					
		22.40	18.76	Standard deviation around average distance					
		17.05	14.14	Arithmetical deviation around average distance					
		350.0	350.0	Desired distance between impact points					
		23.98	22.54	Standard deviation around desired distance					
		18.86	16.80	Arithmetical deviation around desired distance					

TABLE A-VIII

DETAILED DATA 70 DEGREE LAUNCHING ANGLE PINK ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
G1	1-2	342	325	11.0	297	600	268	159	1371
G3	1-2	373	363	7.0	283	580	270	156	1364
G6	1-2	369	343	6.0	258	580	264	162	1367
G8	1-2	303	293	9.5	260	590	266	156	1364
G10	1-2	346	324	6.0	260	560	268	162	1367
H1	1-2	338	328	6.0	240	500	267	156	1365
H3	1-2	349	332	3.0	242	500	268	159	1369
H5	1-2	366	347	4.0	262	500	265	160	1366
H7	1-2	327	307	6.0	210	500	270	162	1363
H9	1-2	374	359	7.0	198	500	267	158	1363
I1	1-2	348	352	1.0	130	440	091	150	1367
I3	1-2	338	347	1.0	130	540	092	148	1367
I5	1-2	358	353	2.0	130	460	091	154	1365
I7	1-2	400	408	6.0	140	520	090	149	1365
I9	1-2	367	376	7.0	140	490	091	148	1367
J1	1-2	337	321	9.5	236	500	265	159	1367
J3	1-2	346	329	7.5	259	500	265	160	1363
J5	1-2	283	270	4.0	240	480	268	159	1365
J7	1-2	365	366	10.5	267	540	270	151	1364
J9	1-2	366	329	9.0	325	530	268	164	1367

As Measured	Corrected	
349.7	338.6	Average distance between impact points
25.34	29.46	Standard deviation around average distance
19.02	22.80	Arithmetical deviation around average distance
350.0	350.0	Desired distance between impact points
25.34	31.59	Standard deviation around desired distance
19.05	24.10	Arithmetical deviation around desired distance

TABLE A - IX

DETAILED DATA 70 DEGREE LAUNCHING ANGLE BLUE ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
G2	1-2	378	371	10.0	274	600	270	154	1369
G4	1-2	372	348	9.0	310	600	268	162	1365
G7	1-2	358	354	5.0	272	580	269	158	1364
G9	1-2	358	340	8.0	255	590	267	160	1366
H2	1-2	365	354	6.0	220	500	270	156	1369
H4	1-2	351	334	7.0	200	500	267	159	1370
H6	1-2	376	362	8.0	293	500	265	157	1365
H8	1-2	348	328	5.0	206	500	272	161	1365
H10	1-2	353	339	4.0	213	500	271	158	1365
I2	1-2	357	360	1.0	130	540	092	151	1367
I4	1-2	365	366	2.0	130	490	091	153	1367
I6	1-2	373	378	3.0	130	510	090	150	1365
I8	1-2	383	391	6.0	145	480	092	149	1364
I10	1-2	336	345	7.0	140	530	091	148	1371
J4	1-2	355	338	7.5	284	500	270	160	1366
J6	1-2	362	361	10.0	273	580	268	152	1366
J8	1-2	351	336	10.0	334	500	270	158	1365
		361.0	353.0	Average distance between impact points					
		11.94	16.83	Standard deviation around average distance					
		9.88	14.00	Arithmetical deviation around average distance					
		350.0	350.0	Desired distance between impact points					
		16.39	16.97	Standard deviation around desired distance					
		13.10	14.00	Arithmetical deviation around desired distance					

TABLE A - X

DETAILED DATA 90 DEGREE LAUNCHING ANGLE WHITE ROTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
G2	3-4	368	360	10.0	274	600	270	154	1369
G4	3-4	347	325	9.0	310	600	268	162	1365
G7	3-4	322	310	5.0	272	580	269	158	1363
G9	3-4	376	356	8.0	255	590	267	160	1365
H2	3-4	319	309	6.0	220	500	270	156	1368
H4	3-4	359	342	7.0	200	500	267	159	1369
H6	3-4	379	366	8.0	293	500	265	157	1365
H8	3-4	414	390	5.0	206	500	272	161	1363
H10	3-4	387	372	4.0	213	500	271	158	1363
I4	3-4	366	363	2.0	130	490	091	153	1366
I6	3-4	348	352	3.0	130	510	090	150	1366
I8	3-4	359	366	6.0	145	480	092	149	1365
J2	3-4	386	370	9.5	259	500	265	158	1366
J4	3-4	346	325	7.5	284	500	270	160	1366
J8	3-4	328	316	10.0	334	500	270	158	1365
J10	3-4	354	340	9.0	320	530	280	158	1365
		359.9	347.6	Average distance between impact points					
		24.66	23.80	Standard deviation around average distance					
		19.61	20.76	Arithmetical deviation around average distance					
		350.0	350.0	Desired distance between impact points					
		27.40	24.00	Standard deviation around desired distance					
		21.75	20.50	Arithmetical deviation around desired distance					

TABLE A-XI

DETAILED DATA 90 DEGREE LAUNCHING ANGLE RED RCTOCHUTE ORIENTATION

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)	Time Between Intervalometer Pulses (ms)
G1	3-4	387	367	11.0	297	600	268	159	1370
G3	3-4	379	369	7.0	283	580	270	156	1368
G6	3-4	346	324	6.0	258	580	264	162	1365
G8	3-4	408	397	9.5	260	590	266	156	1364
G10	3-4	398	373	6.0	260	560	268	162	1367
H1	3-4	344	335	6.0	240	500	267	156	1365
H3	3-4	404	384	3.0	242	500	268	159	1370
H7	3-4	381	358	6.0	210	500	270	162	1360
H9	3-4	372	357	7.0	198	500	267	153	1364
I1	3-4	352	356	1.0	130	440	091	150	1365
I3	3-4	366	375	1.0	130	540	092	148	1368
I5	3-4	391	385	2.0	130	460	091	154	1365
J5	3-4	317	303	4.0	240	480	268	159	1362
J7	3-4	355	356	10.5	267	540	270	151	1375
J9	3-4	370	343	9.0	325	530	268	164	1364
J11	3-4	347	329	8.0	327	500	268	160	1365

As Measured	Corrected	
370.0	357.0	Average distance between impact points
23.34	24.25	Standard deviation around average distance
20.20	19.06	Arithmetical deviation around average distance
350.0	350.0	Desired distance between impact points
31.38	25.22	Standard deviation around desired distance
25.56	21.44	Arithmetical deviation around desired distance

TABLE A-XII

DETAILED DATA 45 DEGREE LAUNCHING ANGLE RED (1000 FT ALTITUDE)

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)
F1	3-4	354	348	6.0	082	1000	210	206
F2	3-4	400	392	7.0	062	1000	210	207
F3	3-4	370	360	5.0	025	1000	210	206
F4	3-4	356	352	5.0	080	1000	210	204
F5	3-4	383	379	6.0	070	1000	210	205
F6	3-4	362	360	5.0	010	1000	210	204
F7	3-4	347	346	4.0	018	1000	210	203
F8	3-4	391	389	4.0	047	1000	210	204
F9	3-4	354	353	5.0	075	1000	210	204
F10	3-4	367	365	4.5	040	1000	210	204
		368.4	364.4	Average distance between impact points				
		16.79	15.84	Standard deviation around average distance				
		14.48	13.48	Arithmetical deviation around average distance				
		350.0	350.0	Desired distance between impact points				
		24.86	21.41	Standard deviation around desired distance				
		19.00	15.60	Arithmetical deviation around desired distance				

TABLE A-XIII

DETAILED DATA 70 DEGREE LAUNCHING ANGLE RED (1000 FT ALTITUDE)

Run No.	Launching Chute No.	Distance Between Impact Points (ft) As Measured	Distance Between Impact Points (ft) Corrected	Wind Velocity (kt)	Wind Bearing (deg)	Aircraft Altitude (ft)	Aircraft Bearing (deg)	Calculated Ground Speed (kt)
F1	1-2	373	366	6.0	082	1000	210	206
F2	1-2	349	341	7.0	062	1000	210	207
F3	1-2	356	346	5.0	025	1000	210	206
F4	1-2	330	328	5.0	080	1000	210	204
F5	1-2	359	354	6.0	070	1000	210	205
F6	1-2	381	379	5.0	010	1000	210	204
F7	1-2	367	366	4.0	018	1000	210	203
F8	1-2	341	338	4.0	047	1000	210	204
F9	1-2	369	367	5.0	075	1000	210	204
F10	1-2	353	350	4.5	040	1000	210	204
		357.8	353.5	Average distance between impact points				
		14.65	16.31	Standard deviation around average distance				
		11.90	12.90	Arithmetical deviation around average distance				
		350.0	350.0	Desired distance between impact points				
		16.58	15.44	Standard deviation around desired distance				
		13.80	12.90	Arithmetical deviation around desired distance				

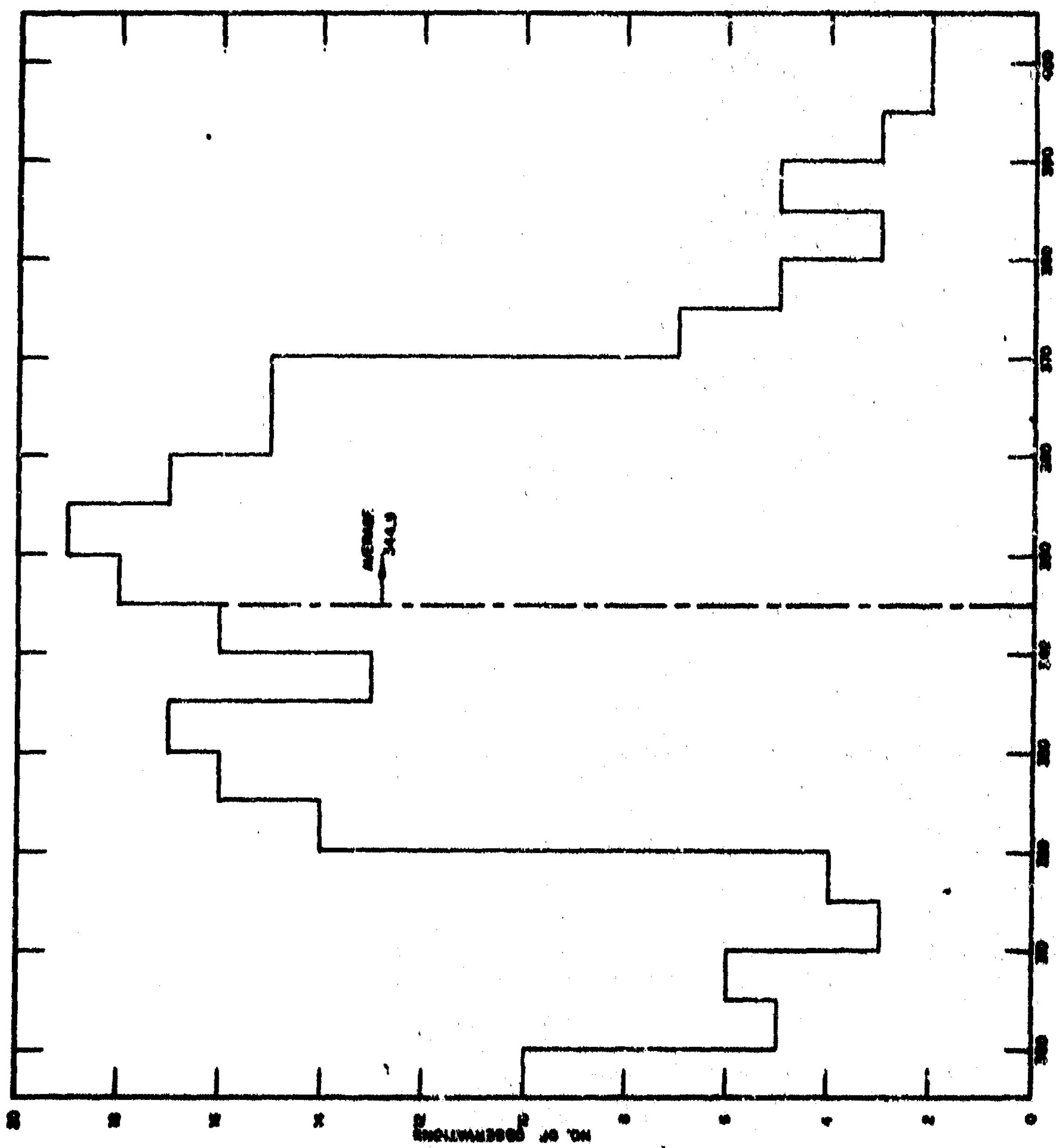


FIGURE A-1 - Spacing Distribution Chart of all Results at all Launching Chute Angles and Rotochute Blade Orientations

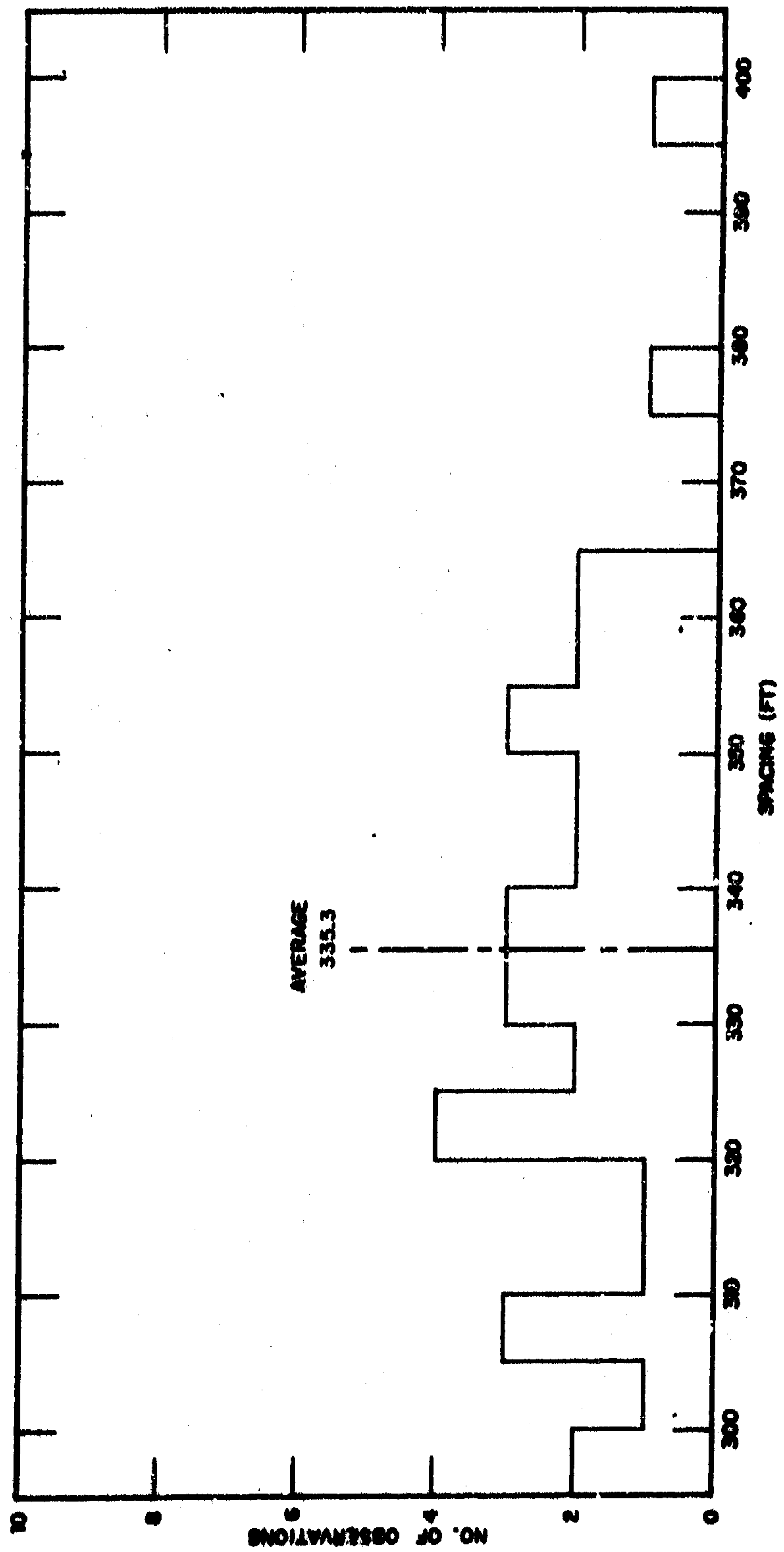


FIGURE A-2 - Spacing Distribution for all 30 Degree Launchings

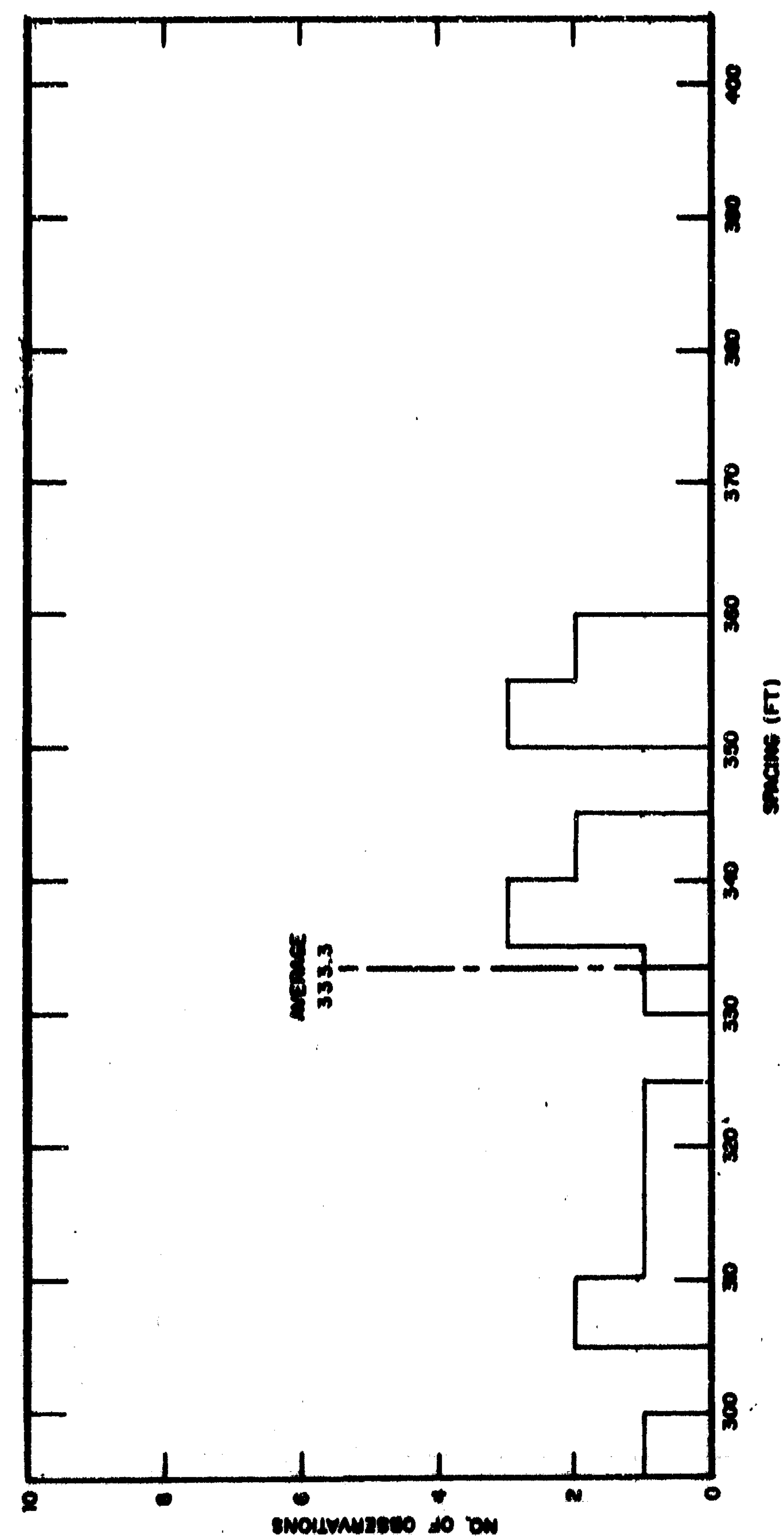


FIGURE A-3 - Spacing Distribution - 30 Degree Launchings with RED Rotochute Blade Orientation

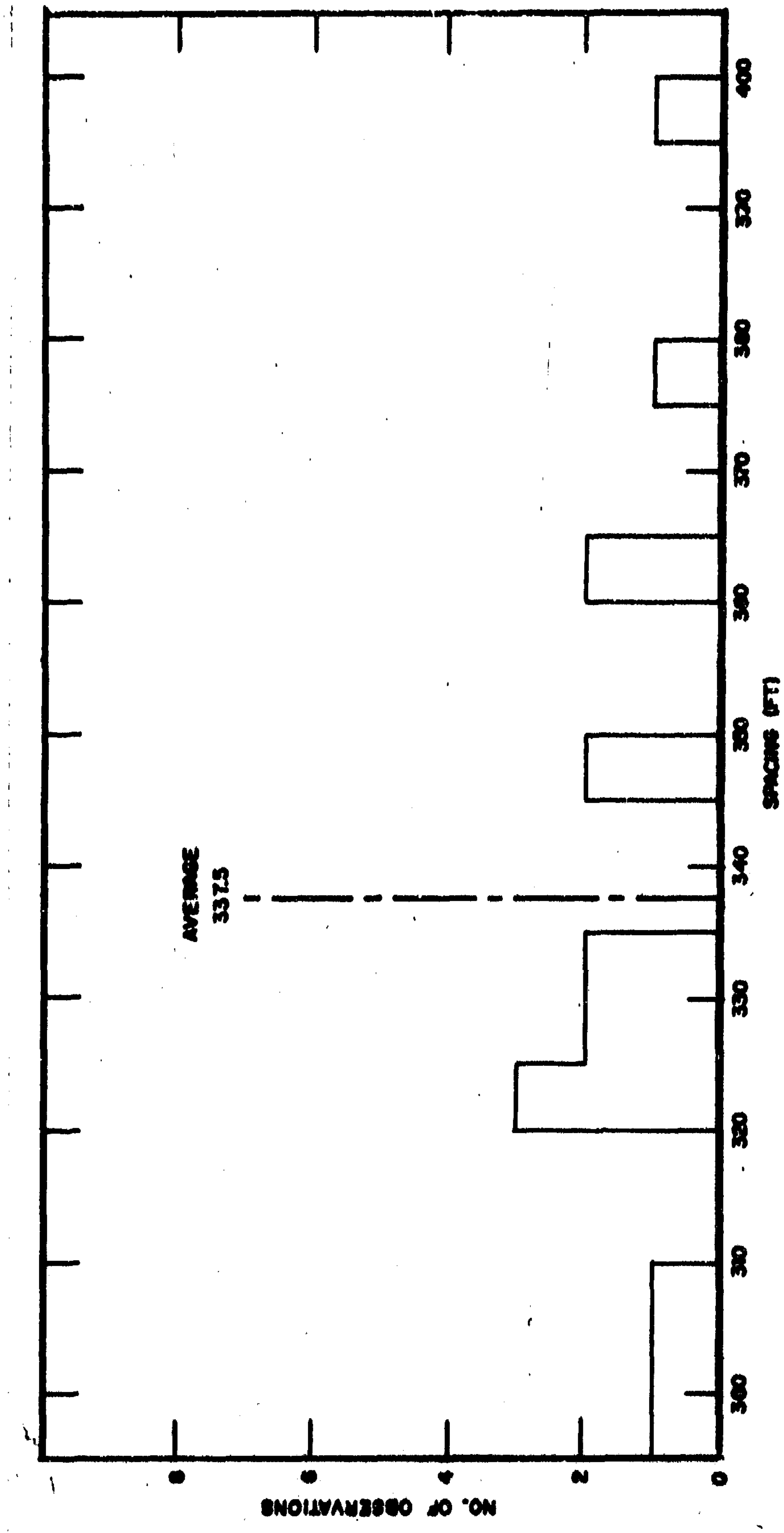


FIGURE A-4 - Spacing Distribution - 30 Degree Launchings with WHITE Rotochute Blade Orientation

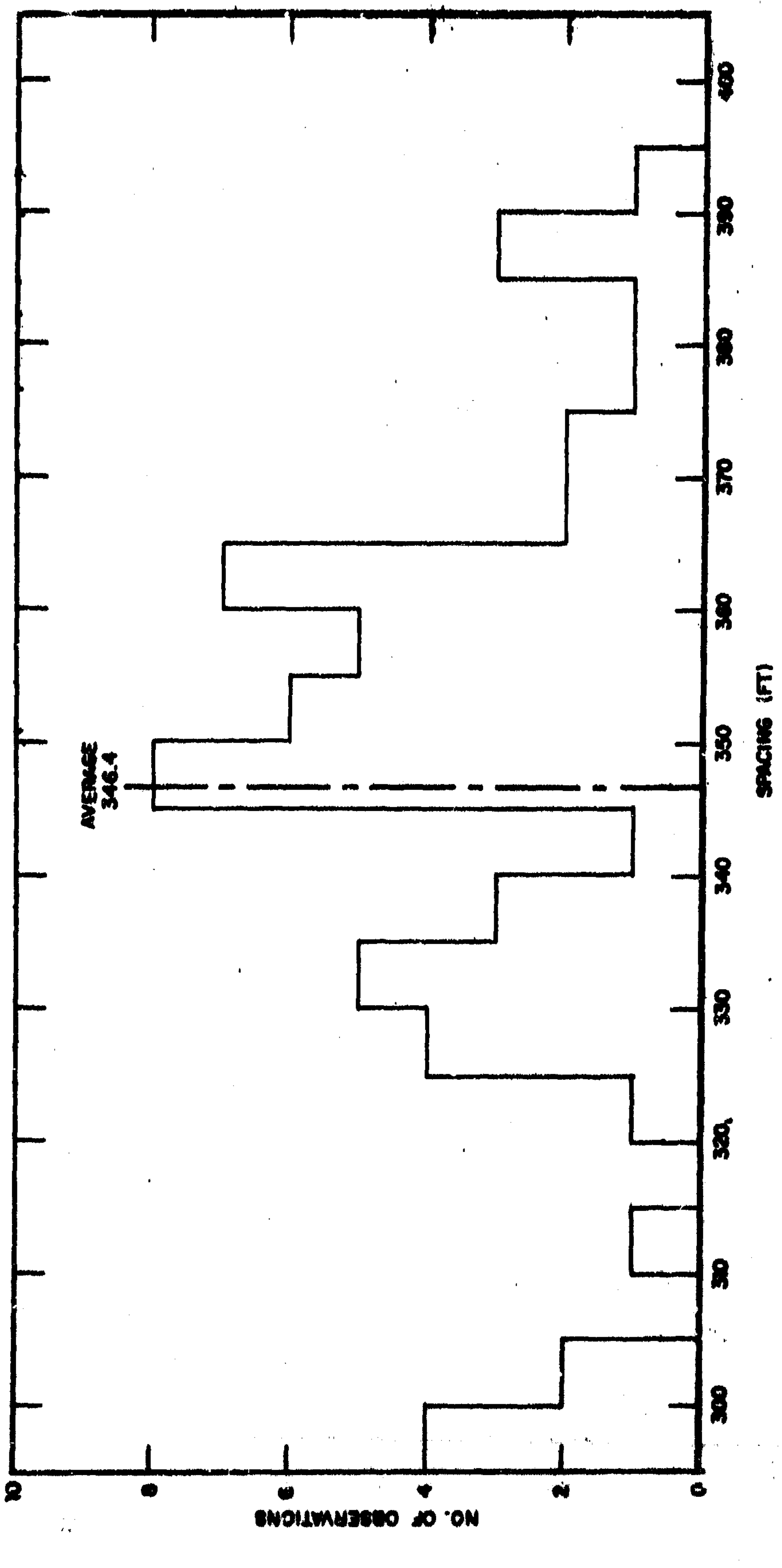


FIGURE A-5 - Spacing Distribution for all 45 Degree Launchings

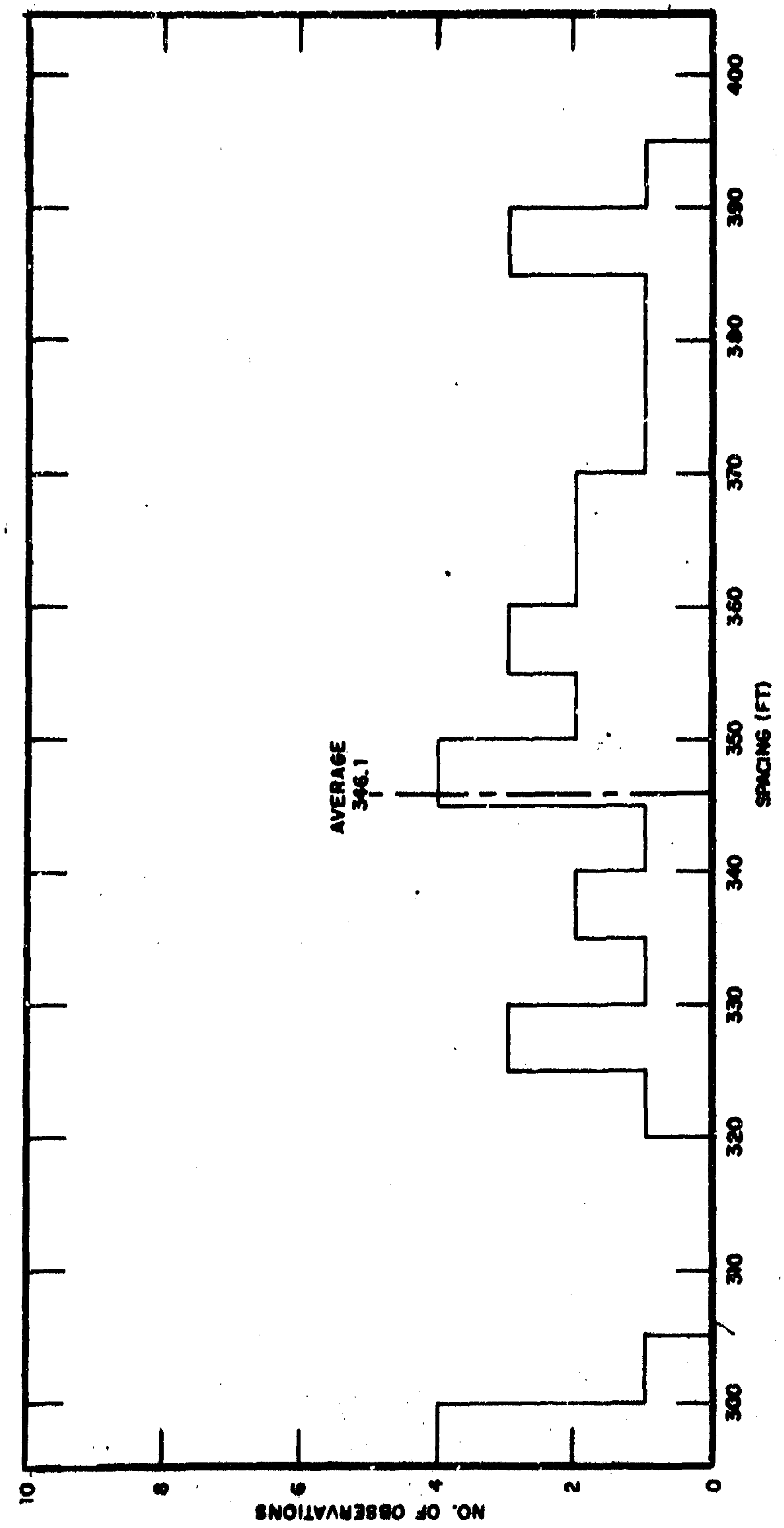


FIGURE A-6 - Spacing Distribution - 45 Degree Launchings with RED Rotochute Blade Orientation

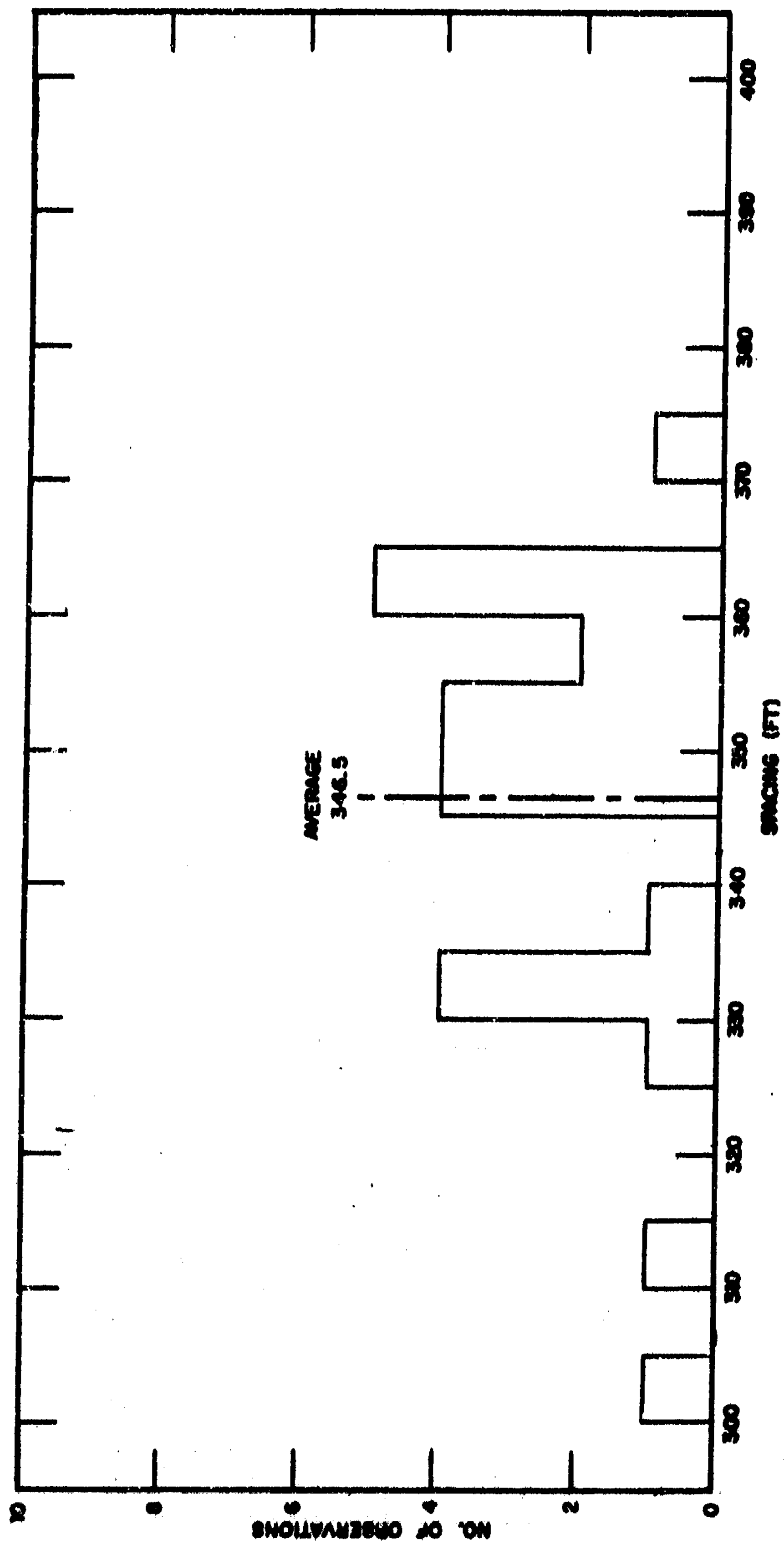


FIGURE A-7 - Spacing Distribution - 45 Degree Launchings with WHITE Rotochute Blade Orientation

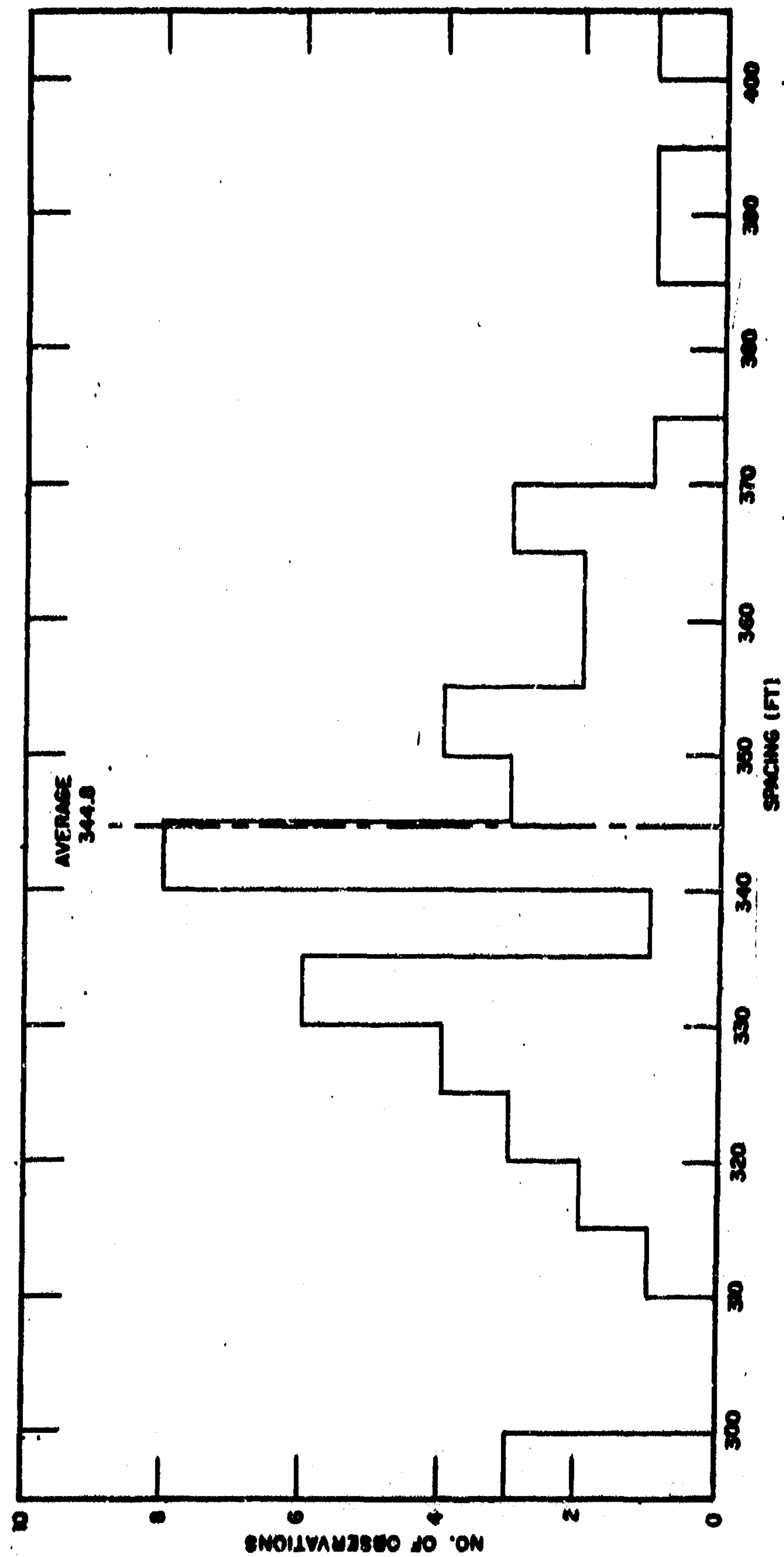


FIGURE A-8 - Spacing Distribution for all 70 Degree Launchings

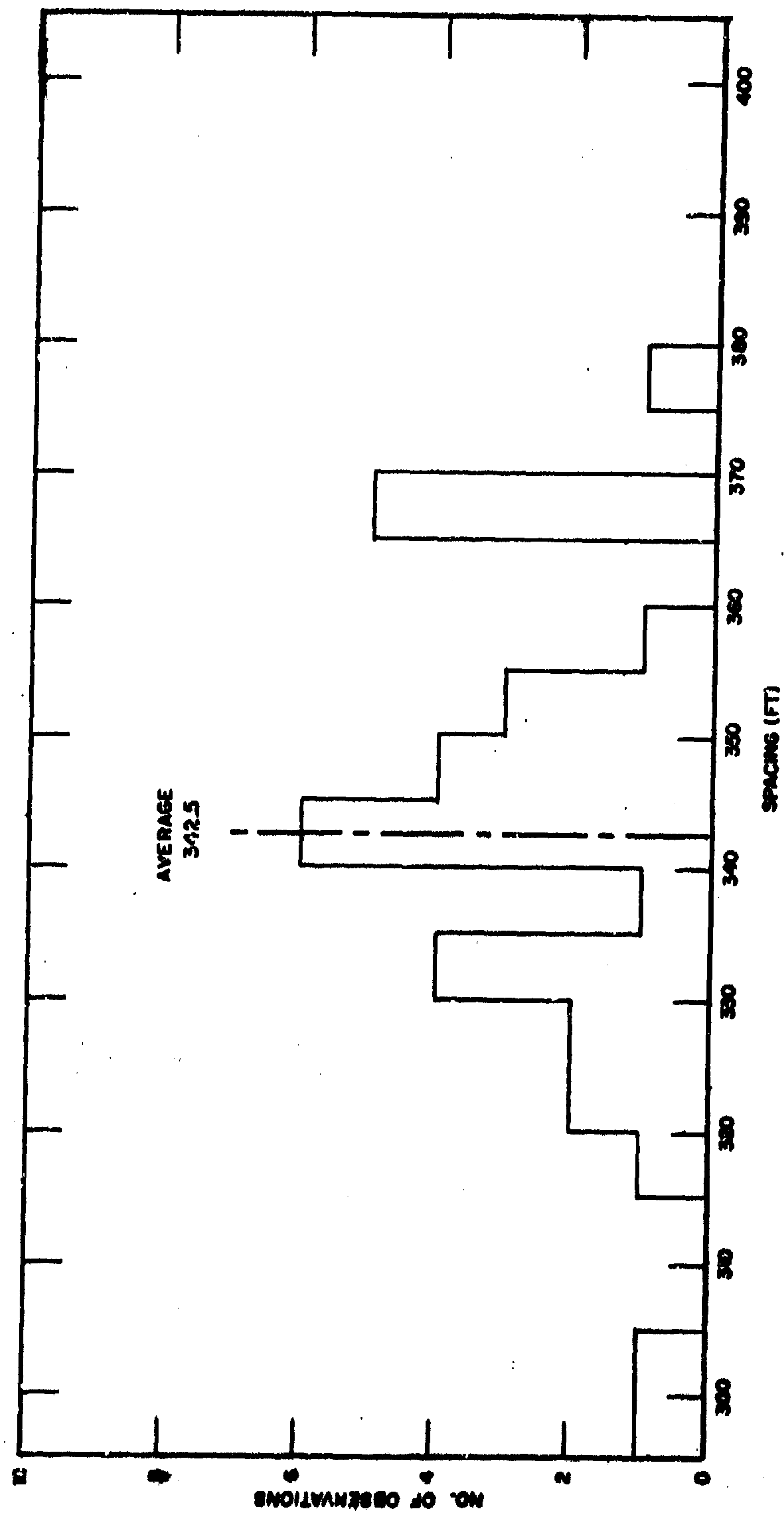


FIGURE A-9 - Spacing Distribution - 70 Degree Launchings with RED Rotochute Blade Orientation

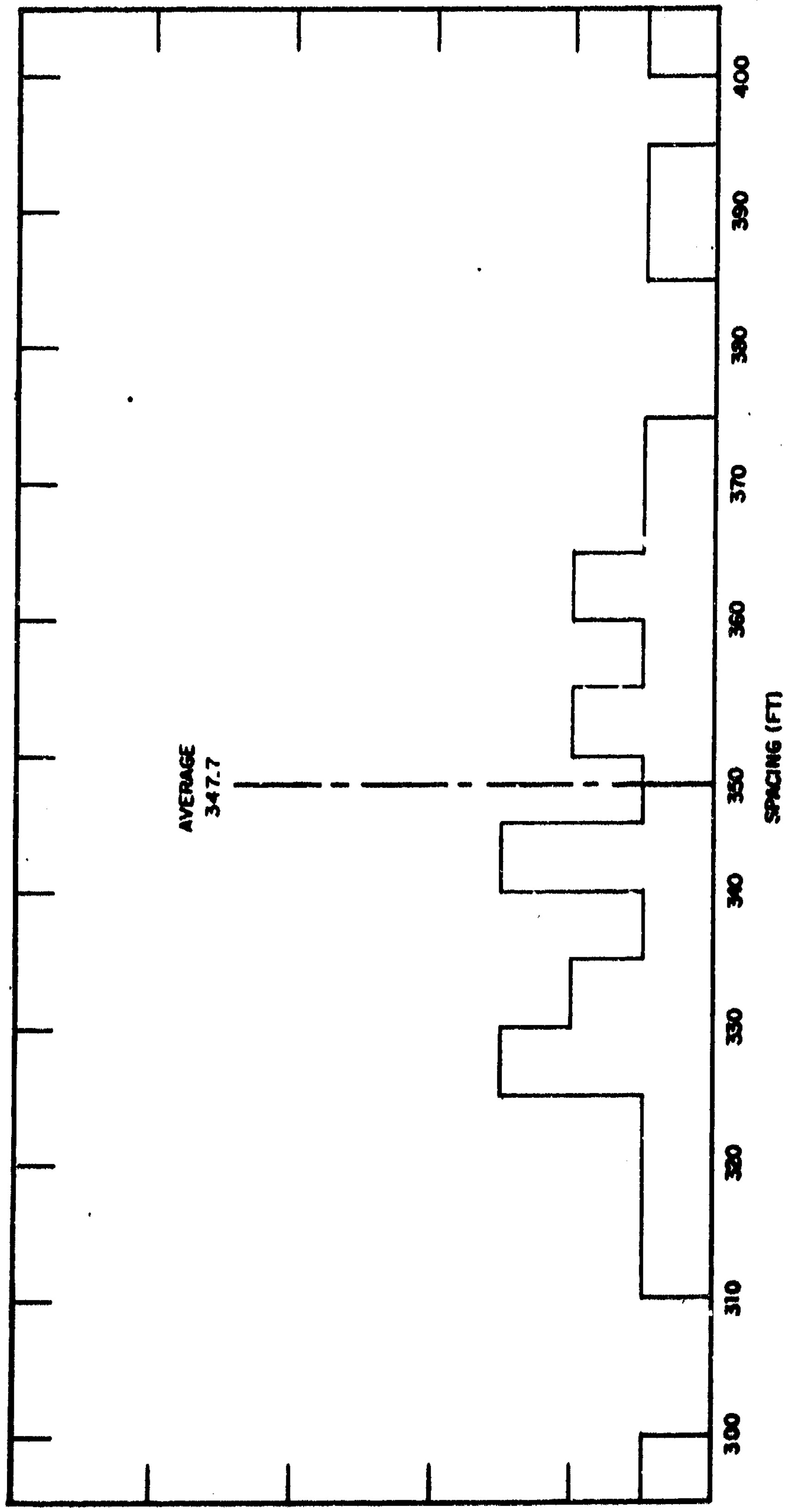


FIGURE A-10 - Spacing Distribution - 70 Degree Launchings with WHITE Rotochute Blade Orientation

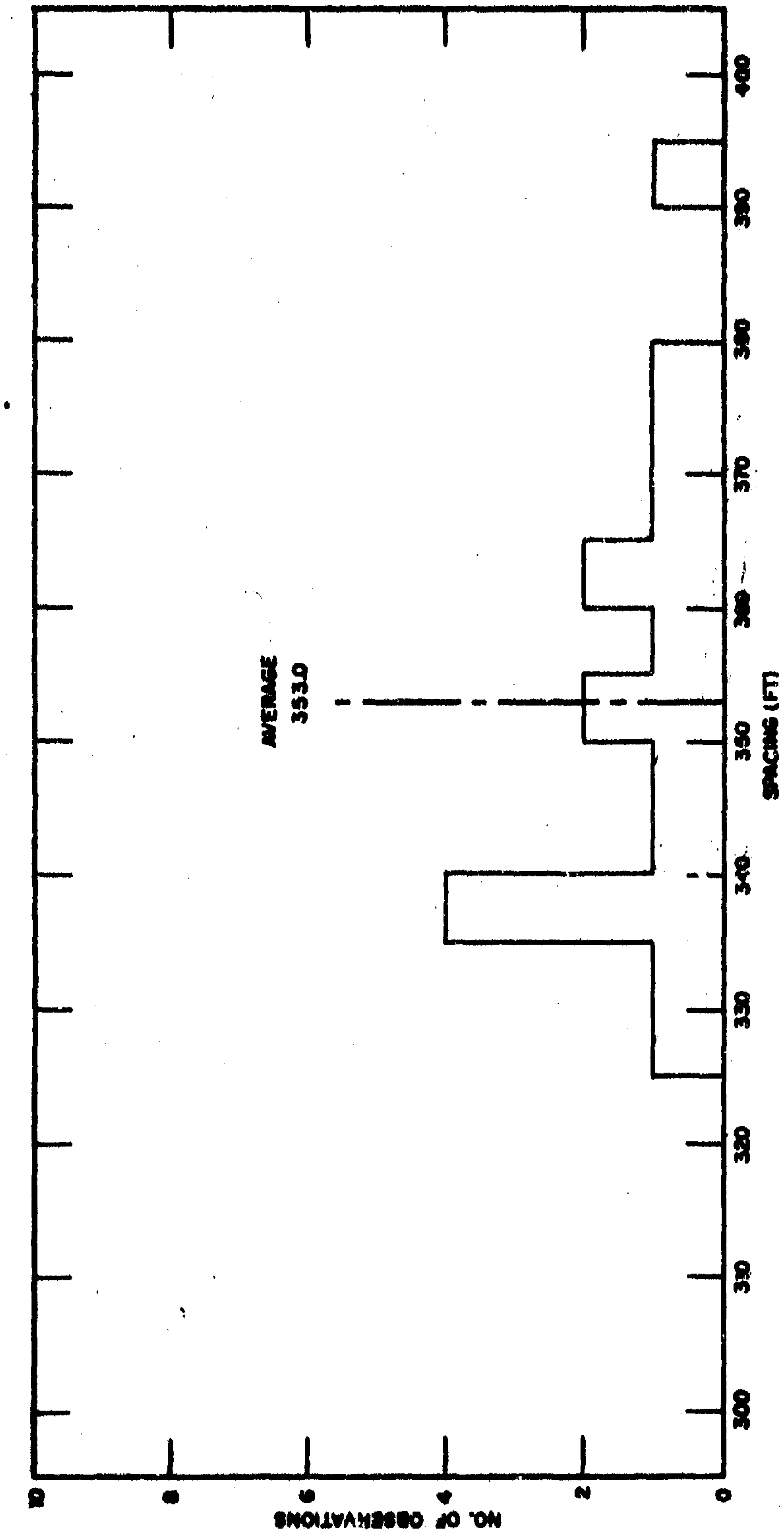


FIGURE A-11 - Spacing Distribution - 70 Degree Launchings with BLUE Rotochute Blade Orientation

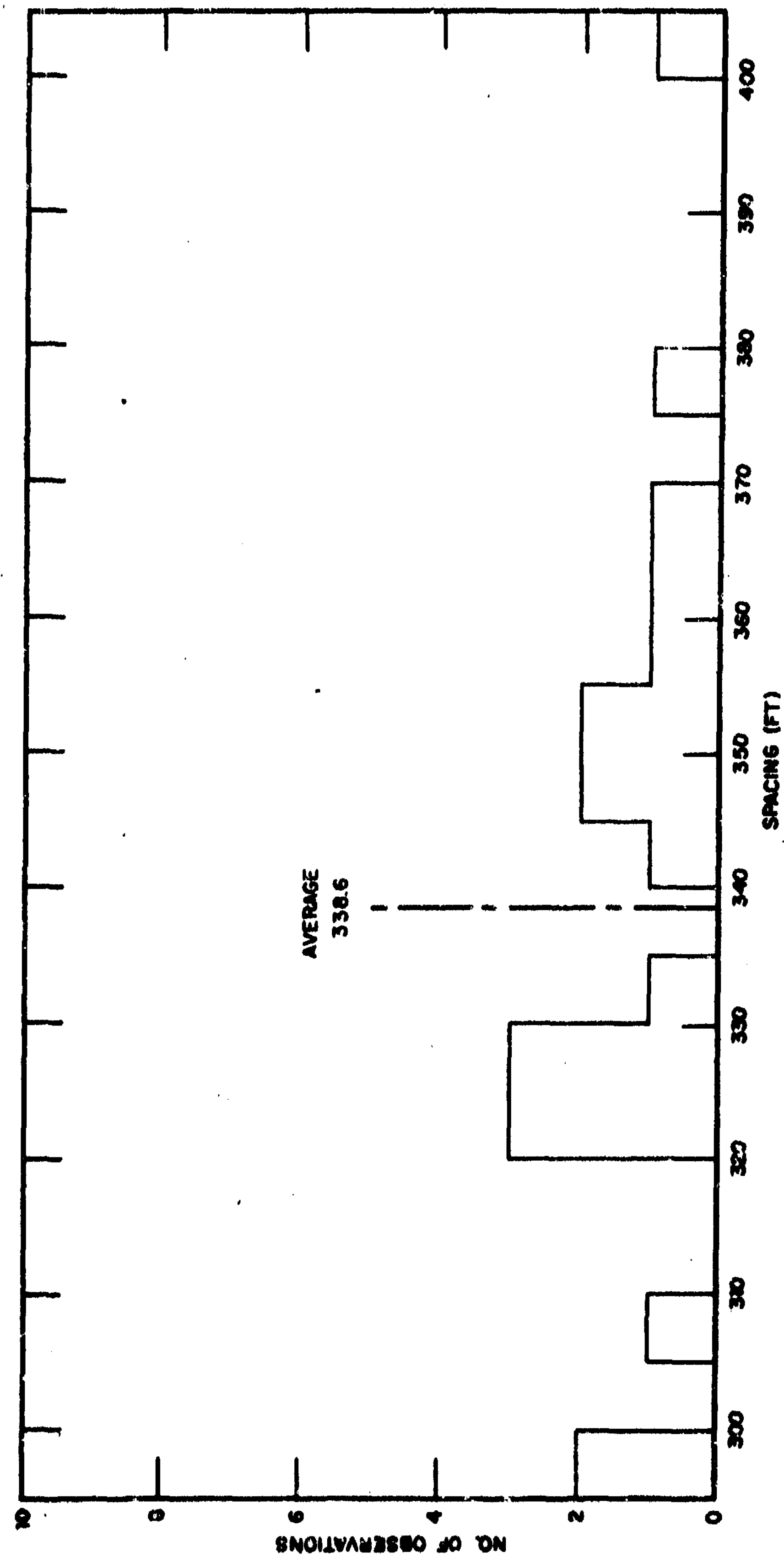


FIGURE A-12 - Spacing Distribution - 70 Degree Launchings with FINK Rotochute Blade Orientation

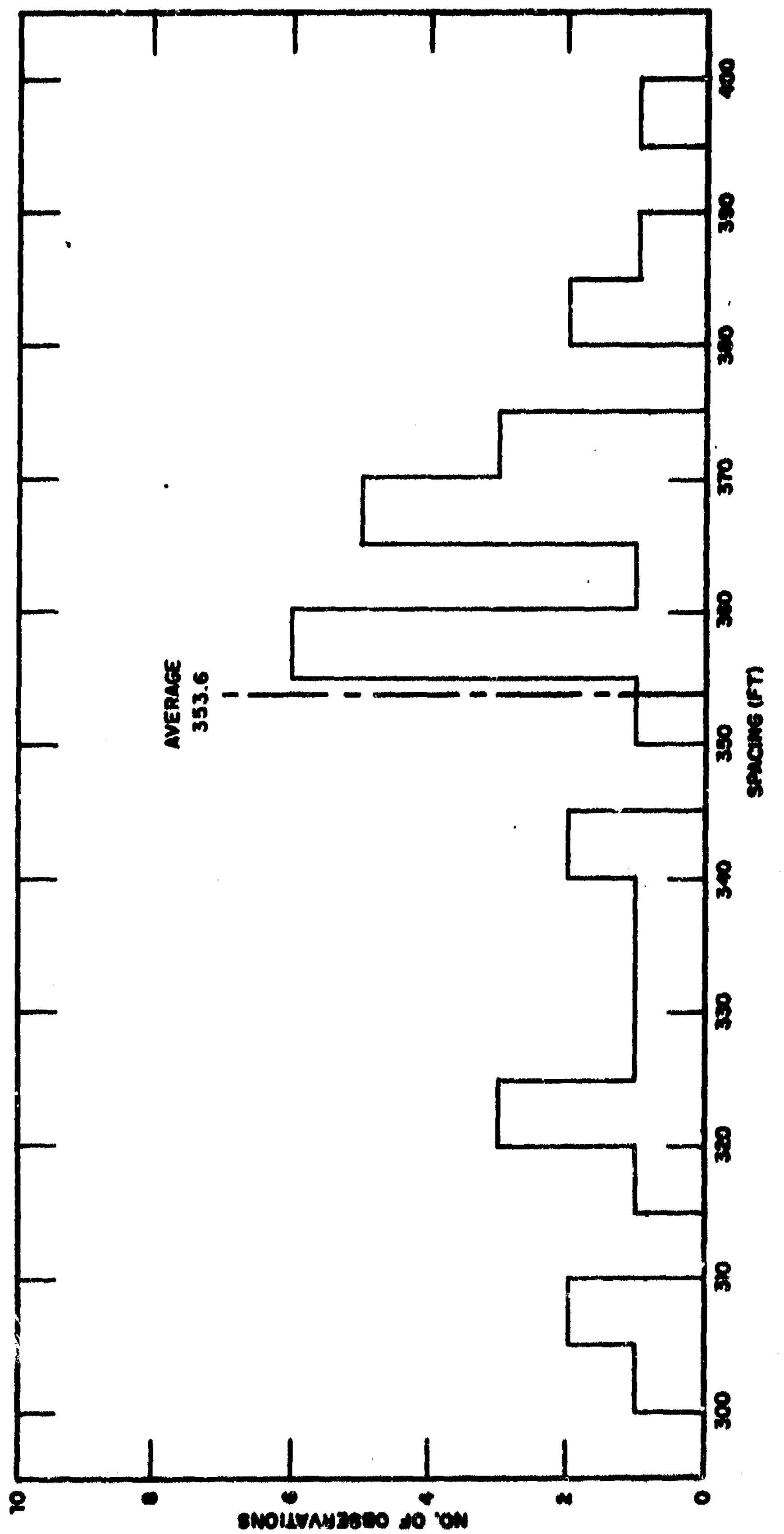


FIGURE A-13 - Spacing Distribution for all 90 Degree Launchings

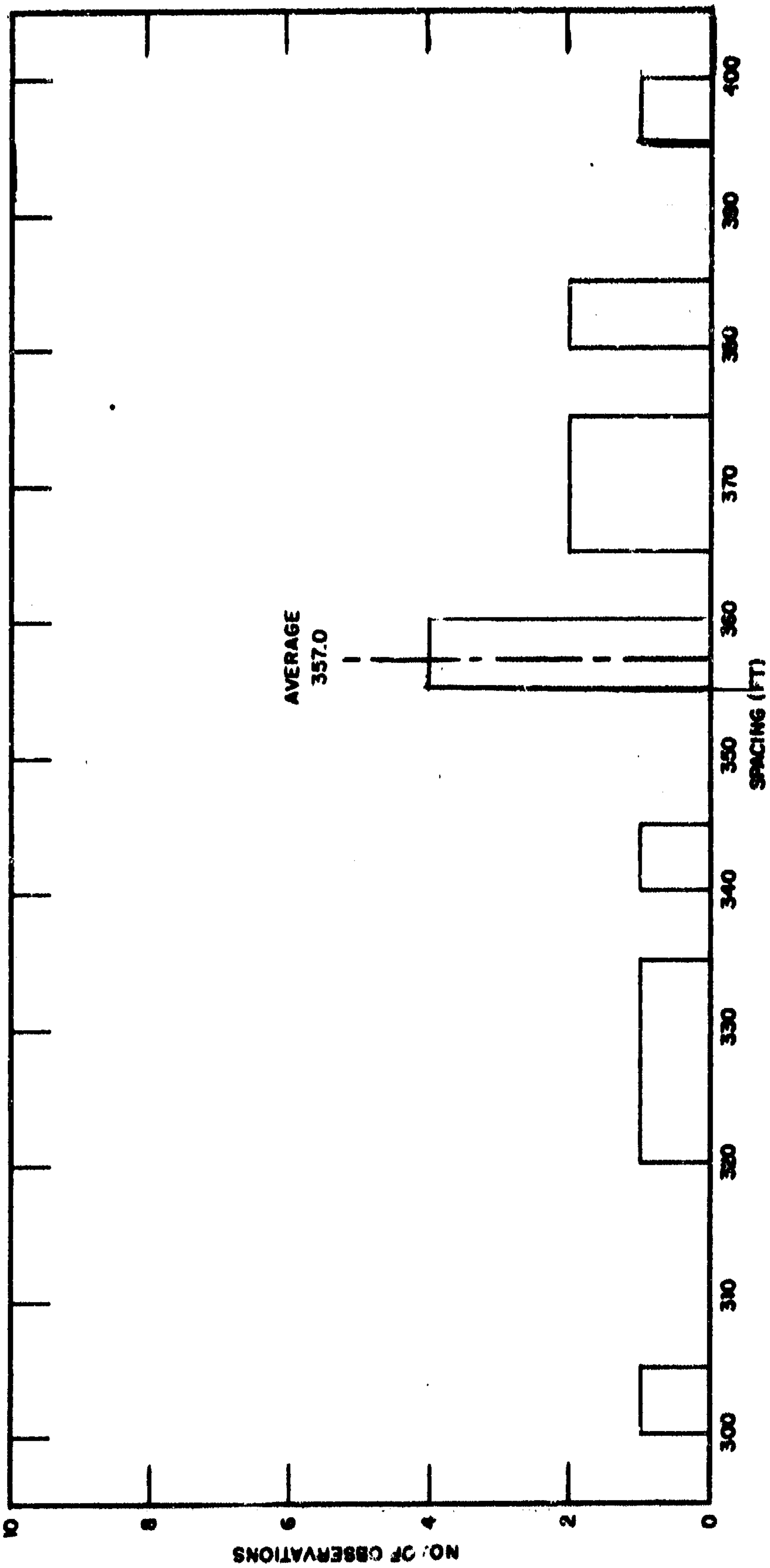


FIGURE A-14 - Spacing Distribution - 90 Degree Launchings with RED Rotochute Blade Orientation

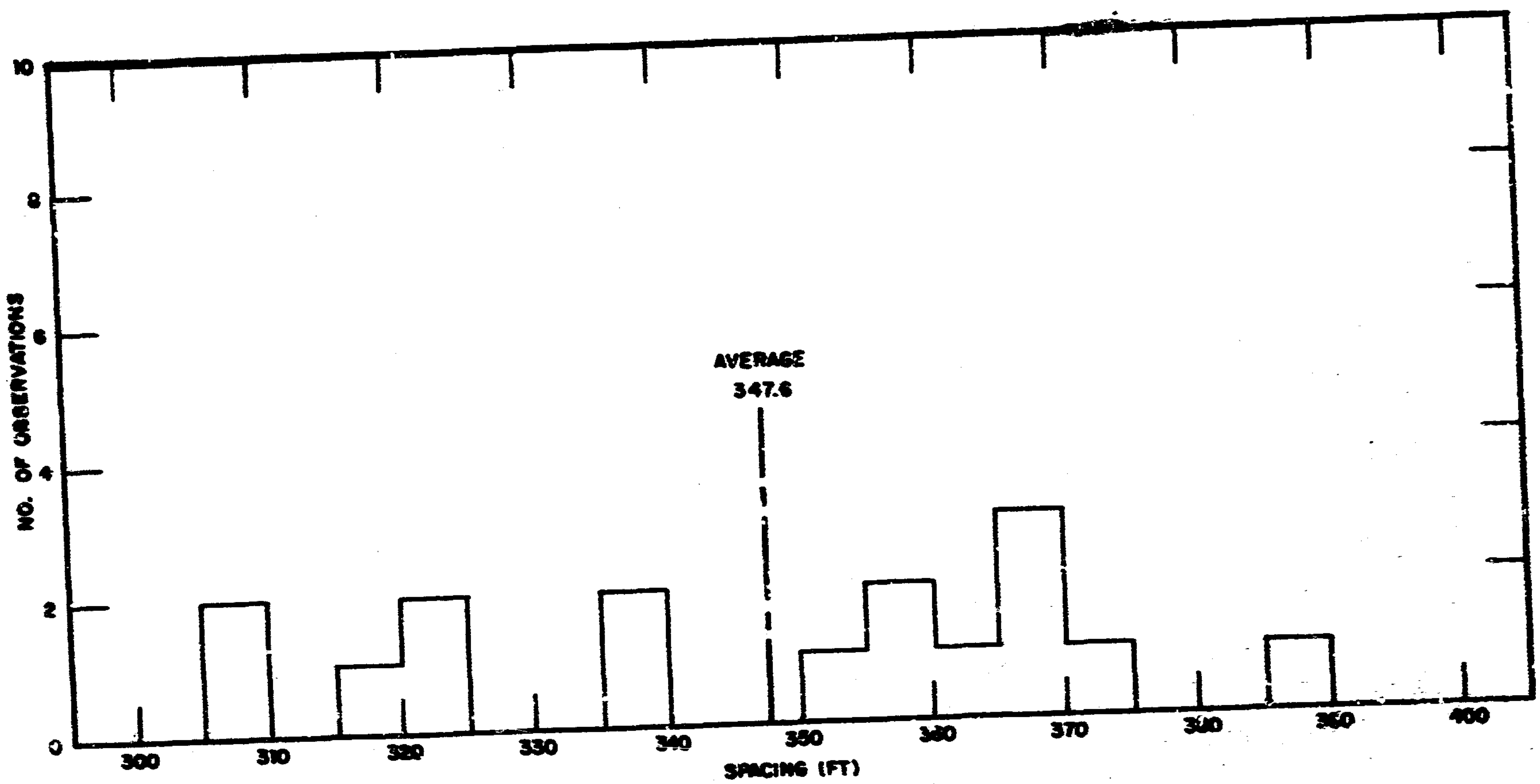


FIGURE A-15 - Spacing Distribution - 90 Degree Launchings with WHITE Rotochute Blade Orientation

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PHASE REPORT, INVESTIGATION OF POSSIBLE IMPROVEMENTS TO SONOBUOY LAUNCHERS AND RETARDATION DEVICES TO DECREASE THE ERRORS FOUND IN SONOBUOY SPACING; by F. G. Amey; May 1961; 70 p; Report No. NADC-AW-6103; TED Proj ADC AV-34054.

This report presents the results of a controlled flight test program to investigate possible improvements in sonobuoy launching and retardation equipment for the purpose of decreasing errors in sonobuoy spacing.

The P2V aircraft standard sonobuoy launching equipment with modifications by the Naval Air Development Center (NAVAIRDEVCEN) to launch stores at various angles to the aircraft horizontal datum plane and orient the retardation means within the launching tube was evaluated under actual flight conditions to determine the effect on sonobuoy trajectory and placement accuracy.

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